CEER-X-030

PROPOSED SOLUTION FOR

ENERGY AND ENVIRONMENTAL PROBLEMS

IN PUERTO RICO

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% CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

é UNIVERSITY OF PUERTO RICO ~ US. DEPARTMENT OF ENERGY

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INTERNAL ?CIRCULATION

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UNIVERSITY OF PUERTO RICO

?CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

PROPOSED SOLUTION FOR ENERGY AND ENVIRONMENTAL

PROBLEMS IN PUERTO RICO

May 17, 1979

---Page Break---

Page

16

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Legislative Appropriation---?--???----?---?---- 17.

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Miscellaneoug Funding Sources

Proposed Legislation

Independent Research Center within UPR

Examples of Possible Scenarios in Energy and

?and Environment

Long Range Forecast of Energy needs in'Puerto Rico

Proposed Puerto Rico Research Institute

The need to explore alternative energy sources

for Puerto Rico

---Page Break---

NUMBER

38

LIST OF TABLES

DESCRIPTION (ABBREVIATED)

Proposed Transition Funding Level

Estinates of Puerto Rico's Energy

Requirenents

Schedule of Proposed Sce

Objectives

wrios Program

Possible Million Barrels O{1 saved

with Scenarios

Potential "Energy and Cost Reductions"

Possible CEER Revenues from Fuels

Tax Rand D Law

Total GEER Funds Requirenonts

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EXECUTIVE sunny

?Te Center outlines it's proposed solution for the oainous problems of

?energy and environment which threaten the well being of the Puerto Rico

conmmity. In a national and interational context selected alternative

?energy sources and concomitant environsental problems are elaborated.

Necessary funding and possible sources are analyzed, The unique po
of GEER in ability to exploit the advantages inherent in the Puerto Rico
site are included.

?The poasibilictes of exporting technology are presented. Relationships
with U.S, Departaent of Energy, the Comonvealth Energy Office and the
University of Puerto Rico are discussed.

Basic conclusions are (1) Puerto Rico's energy crisis demands an expand~
ed role by GEER in R 6 D vhich previous levels of funding and institutional
relatfonships cannot sustain, (2) with adequate funding CEER can convert the
Uatversity of Puerto Rico into a technology exporting organization with
special relevance to the Caribbean, Latin America and other areas in tlie
elds of OTE, Bioaass, Photovoltaica, ethanol and solar stean. (3) the
scale of operations and funding level of CEER are not adequate for perform
jing the research and development role in Puerto Rico's energy crisis.

(A) No alternative institution of equal capacity for euch role is perceived
to exist in Puerto Rico. (5) Without adequate support for R & D the enersy
exists will reach disastrous proportions.

Recomendations are (1) that the appropriately redefined role in R'6 D

be.assigned to the Center aid that necessary funds be provided, (2) That CHER remain as a unit within the UPR, but be peraitted to retain its

innovative practices. (3) Mes with the Office of Energy be strengthendd,

?and (4) Proposed legislation on funding receive the endorsenent of the

President.

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TTXTRODUCTTON AND BACKGROUND,

Reorganization ia the Federal government since ?he founding of Puerto Rico Nuclear Center (PRNC) under the Atoaie Eneray Comission (Ac) in 1956 has resulted in the establishment of the Center for Bnergy and Eavironnent Research (CEER) with a new aivsion and found ?ing structure. The nove in 1975 to start the process of making the Center self sustaining and competitive aas necessitated the adoption of new strategies for conducting research and finding new funding sources. Tn these efforts CEER has been quite successful. An exa~ mination of progress tovard self-sufficiency has revealed inportent implications for the long term success of the Center. Im planning now for the future prograns and funding for the Center, considerations aust be given not only to assuring continuity and development of the

Center, but more importantly to ite ability in solving the pressing problens of energy and environsent with which Puerto Rico and the whole nation are confronted. The problens in Puerto Rico are great and will require investment of resources which aay have not been con sidered possible five years ago.

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

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mL.

?THE PRESENT SITUATION AT THE CENTER

The Center counts as its principal resources fourty three scientists with an established reputation for productivity and responsiveness to the Department of Energy (DOE) needs especially in the areas of tropical ecology, nuclear research, education and more recently in alternative energy source developnent. The research facilities valued at $12 millions are the best in the Caribbean and the FY 1979 budget amounts to approximately 3.5 illions dollars of which about 2.2 millions represent base funding. The Center has been more successful than expected in securing funding from competitive sources during the first chree

years of the transition period (having

cured $900,000, compared

to a predicted $150,000 in Fr 1978).

A. Prospects for the Continued Developsent of CEER After Septenber 30, 1981.

?hen in 1976 it was decided that the Canter should begin

the traneition fon 4 DOE contract facility to integration

within the University of Puerto Rico the budget was $2,706,000

of wich §1,230,000 ae ?base? money for training and education.

$294,000 was from competitive grants and the remainder in BER.

The decline in bate support from DOE may be noted. Te is

particularly ingortant in che Light of che fact that the UPR has

not provided substitute finde,

the difficult

resources wanagenent problen faced by the University Administra-

tion and regrets the circumstances in which the UPR's commitment

) See Table 1

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of support has not been fulfilled in accordance with the
provisions of the DOE (EEDA) action memorandum of April 16,
1976.

Faced with the prospect of daclining base support and
with it the resources to adequately pursue new sources of
funding a decline is foreseen in the ability of the Center

to respond to Puerto Rico's needs as it has been in the past

LL. FUTURE PROJECTIONS

A. Rovised Mission

The new mission of CHER is to address energy and environ

went questions that arise for the industrialized, tropical

island of Puerto Rico and to do so in a vay which has maximum applicability to other areas.

Puerto Rico needs expert information to guide planaers in the orderly developnent of the island. Orderly developaent requires the objective assessuent of energy alternatives in the context of their environmental and economic costs. CHER is the only institution on the Island with the appropriate orientation, tradition, independence, reputation and expertise

to perform this necessary task.

Competitive Funding Prospects

Wile DOE funding of relevant research is expected to

continue it will become a snsller fraction of the total

program needs. liovever, it is unrealistic to expect that

the observed rate of increase of competitive funding can be sustained. There is need for research in other areas for

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?which GEER is logically the condidate but the dollars available fon the Island are finite and consequently the Center vill nore and nore have to enter into competition with other established research units for money from the United States and other sources, This will require an incressing expenditure of effort fon the part of CEER staff. This is a contingency for which Litele provision has been made in GEER structure to date.

Using the national average for the rate of rejection of research proposals it may be conservatively estinated that 1.3 man years per year must be spent in grant proposal preperation to yield

1 million dollars of competitive funds.

Research to Secure Environmentally Acceptable Energy,

?Alternative

Vigorous efforts will be required to solve the special enersy

?and environmental problé

for Puerto Rico. CHER is already

involved in prograns having the appropriate orientation, but

?much more work will be needed to solve the problem. Several

cases may be cited as,exanples of the relevance and cost effective

ness of CEER?s present and planned R & D prograns which have

relevance for the Comonvealth.

OTEC, photovolteic, bionsss, ethanol and solar stean are

under consideration as altemative energy sources for Puerto

Rico, More detailed information regarding the K & D scenarios

for these aay be found in Appendix D.

Considering OTEC as an illustration, plans call for «

40 Mi plant generating about 1% of Puerto Rico's, energy needs

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by 1985; a 250 Mi Denonstration Plant providing about 42 of energy requirements by 1990; and a possible 500 Mi addition

to the electrical generating capacity bringing the OTEC total contribution to about 12% by the start of the 2ist. contury.

For each of the energy alternatives assumptions, costs and environmental R 6 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 Dut needs to be adapted and expanded for Puerto Rico to make ?any sort of reasoned approach tovard energy independence. (CHER is the only agent on the Island capable of and already involved in such verk for Puerto Rico and CRER will not without assurances of base funding be able to continue this leadership role.

?The sumary of the examples scénarios considered, under crash type R & D Program heavily involving CEER, is given in

Tables 2 to 6.

?Table 2 includes an eatinate of the energy requirements in Puerto Rico for the period 1976 through 2000. rt is ?assumed that the present socio-econonic structure persists ?and that no R 6 D progran in search of energy alternatives is functioning. The fuel bill for Puerto Rico during the FY 1979 exceeds one billion dollars and the total bill for the reat of thecentury ie estimated at approximately 156 billion dottare. (2)

(@) Coluan 6, Table 1.

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?TABLE 2

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

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3973 | 26.0 17.0 25.1 T2705 Toor

3980 | 27.5 17.3 263 16.78 1203

398 | 23.0 18.5 ZT 39.17 4442

3382 | _29.7 13:0 29.1 21.307 1704

1963} 318 13:8 30-5 25.007 2055

1984 | 33.6 32.0 28.55 2458

1985 33.6 32.70 2339

1986. 35.3 36.29 3390

4987. 3721 40.28, 3903

1988 38.9. 44,72 4633

7969 40-9, 49-60, 5396

1380 42.9 55.00 6266

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1992 a3 62.75 7856

1993 49.7 ?67. 00 3235

1996 Bar 715.0 3796

1995 a8 76550, 70928

1996 375 Bitz 712078

1997. 60.4 186,00, 13347

1398 63.4 ETRE 14793

1999 66.6. 36.62 716290

2000 28-1 69.9 702.6 718016

roma. $155,029

(1) Statistical Correlations between population and GNP and between GuP and Electrical Energy Generation. Correlation 998. See Appendix x

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

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

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

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Table 34 presents an illustrative program of energy alternative objectives under a very tight schedule which will only be achieved

by a concentrated and coordinated effort between the various

government energy planning related organizations and in which

GEER is the main R&D researcher. The contents of the table

faze the anounts of pover in electricity, steam, ete. which could

bbe achieved in the period indicated.

?Table 3B indicat

the anount of of1 saved by the proposed

rash program by the indicated scenarios.

?Table 4 itlustrates the potential contribution of the

proposed energy alternatives scenarios to the total fuel oft

consumption of Puerto Rico, A reduction of nearly 52 billion

dollars equivalent to 36% of the total dollar expenditures up

to the year 2000 is indicated. This large anount is probably

the maximum saving which could be achieved since it is predicated upon a very tight echedule and R & D crash programs requiring inter-agency coordination and cooperation.

Table 5 illustrates « possible source of revenues to finance the R & D program. A fuel tax for energy and environnent=41 research and developnent 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 2.5e 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.

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

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SCHEDULE OF PFOPOSED SCEWARICE PROGRAM OBJECTIVES

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(1) At east 9-50006 base toad units will be required in the period considered.

ieaitiona) fossil fueled waits nosde to be added,

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POSSIBLE MILLIONS BARRELS OTL SAVED HIT PROPOSED SCEEARTOS

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THIORNOLATCS Tease Tar

yean| ome | evscre. | Steam Gasohol| miectsie(a] orem | -somacs

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ager] 233 5a Tae Pao 70.94

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3995 [49.53 3.53 [3.7 70.6 50 52.8

396] 10:53 ?[7.00} 7-4 70:6 =: cm

ser [17-20 [7.0078 19:6 a 65.381

Tee [36a {7.00 ?[7-4 19:6 73.35

1999 [30:8 7.00] 7-4 10.6

000-(30:5¢ [7.00] 7-4 106

(2) atinated 60 kv par ton of (S16 moisture) baggeee.

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TABLES

POSSIBLE CHER REVENUES PROM FUELS TAX RED LAW

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YEAR

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1986. 7.46 [-a1

1987 12;89-[-37

1988 12:83 [33

1989) 12.81_[-30-

1990) 12.02-[-27

1991 12.92 [26

1952 WaT [oe

1993 13.85 -[-22

1994 13.92 [21

1995 53.49 [-20

1396. 13.32 [18

7397 33.32] -17

1398) 13.34 | 16

7999) 13.29 16

2000 14.34 | 15

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Table 6 {llustrates the total CEER funds requirements for the illustrative scenarios. The last tvo coluans of Tables indicate. the suggested source of funding.

Column 13, labeled ?Base Funding Requirenents? in Table6 is the minimun projected funding requiresents for CEER. If the proposed exasple scenarios or any other similar type progran is not undertaken, CHER still needs to be funded to ehe level shown in the indicated colum. This is discussed nore fully in the section below.

?An adequate attempt to solve the energy problens of

Puerto Rico vill require that during the period 1980 to 1990

4a total of approximately $199 million (3) be made available

?This represents an average investment in R & D for energy

and environment in the vicinity of $18 million annually.

ALTERNATIVE INSTITUTTONAL FRAMEWORKS

Faced with the problem of continuity and growth the Center

?has considered the means of assuring both. The alternatives are

dealt with briefly below. More extensive versions are contained

in the Appendices.

A. Continue within the existing organizational structure of

UPR and extend the present relationship with DOE.

DOE is well avare of the capabilities of CEER and

Pro

ie Likely to approve soae continuing relationship.

Pro 2+ The UPR is Likely to continue to look favorably

upon CEER activité

?and give it vholehearted

support.

@ Column 1%, Table 6

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Pro

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Continuity will not require any adjustaent to the nev
perspective which aight be required if new sponsor
or organizational loéstion results.

Levels of funding will not approach the anounte
required in axl adequate program as outlined above,
Increases in funding from UPR are not Likely to be
forthconing given the percentage commitment which has
been realized in the past.

Te alternative will not provide the dynamic organize
hon and 4

jonse which Puerto Rico's energy and energy

research problens denand,

B. Integration with the Puerto Rico Office of Energy to

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A total integrated approach to the probless of enersy

would result.

More efficient utilization of resources night be

achieved.

Possible sponsors or funding might be attracted by

the coubined efforts,

?The executive branch of government is not supportive

of resi

urch activities. ?Operational? and "Service"

considerations usually outveight research needs.

Full integration within the public service might
rigidify the organization and might lessen the
responsiveness and flexibility which have characterized

ie until now.

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c

con 3+ Anew Department of Energy would suffer the normal

growth and development problems in a new bureau~

cratic structure. How long it would take to get

beyond ite ov problens of organization to those of

?energy and environaent is an open question.

Establishing an Independent Private Entity

Setting up a cospletely independent private organization

?Right prove attractive to some but the divorce fron the

University would be against the philosophy of the Center which

perceives its role as a weuber of the University coommity.

Bonds with the UPR system do not prevent the Center from

facilitating work with private universities. At present such

activity is an ongoing part of the functioning of the Conter.

Modifying Present Acrangonents with UPR

Te is obvious that CEBR is well able to function as an

autononous research institution. Perhaps then, the idea of

dite being a wholly detached, essentially private institution

should be explored, This exploration could take into account

the histories of the Michigan Engineering Research Institute, Southwest Research Institute (University of Texas), Jet Propulsion Labs (Cal Tech), and counterparts at Harvard, Stanford and Carnegi¢ Mellon. While still closely related to their respective university systens, these organizations operate as integral corporate structures. Control is still exercised by the University through represestation on the

Board of Directors, but day to day managenent and finance

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functions are carried out by the adninistratore of the research institution.

Objections to this arrangenent can be expected, resistance ight be overcone by paying dividends on stocks or interest on bonds to the University and by @ contractural agreenent to

provide Limited free research assistance and facilities. The

advantage to the University would be an immediate reduction in operating costs, and if CEFR were successful, there would be

the potential of s good incone from both Government and private

FUNDING ALTERNATIVE - THE BASIC PROBLEMS

Legislative Appropriation

Various alternatives of CEER funding were 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 de 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 $518 million dollare snnually.

A very low probability of success was given to thie alterns~ tive.

(e) Request to the Legislature to allocate to CEER part of Puerto Rico Water Resources Authority (PRVRA) contribution in lieu of

taxes. Lav 83 of May 2, 1941 requires PRNRA to contribute with

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Sx of ite gross revenues to the State General Fund. However,

recent amendnents has committed fully this contribution in

relation with the fuel adjustment claw:

subsidy given to

consumers with less than 400 kvhre monthly. The alternative

was discarded.

(@) Request to the Legislature for fixed yearly allocations in the

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

allocations history was reviewed), Due to the present tight

government budgetary conditions a low probability of eucce

vas assigned to this alternative.

(©) The enactnent of @ new bill inposing a tax of 1.5-2.5 cents per

silliion BTU on all Saported fuels consumed or sold in Puerto

Rico to finance CHER prograns. Appendix B describes the proposed

Legislation. This is considered the most logical alternative.

+ CONCLUSIONS

1, Puerto Rico's energy crisis demands an expanded role by CEER in R&D which previous levels of funding and institutional reletion?

ships cannot sustain,

With adequate funding CHER can convert the University of Puerto Rico into @ technology exporting organization with special relevance to the Caribbean, Latin Anerica, and other areas in the fields of OTEC, Biomass, Photovoltaics, Ethanol and Solar Steam.

3. The scale of operations and funding Level until now were adequate for transition from the Puerto Rico Nuclear Center to the found=

ing of CEER, They are not adequate for performing the research

and development role in Puerto Rico's energy crisis,

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var.

No alternative institution of equal capacity for such a role is,

perceived to exist in Puerto Rico.

Without adequate support for R & D the energy crisis vill

reach disastrous proportions.

RECOMMENDATIONS:

1, It ds recommended (1) that the appropriately redefined role

in 6 D be assigned to the Center and that necessary funds

be provided, (2) that CHER romain as a unit within the

UPR systea, but be permitted to retain ite innovative

practices, (3) that tieswith the Office of Energy be

?strengthened, (4) that proposed legislation. on funding?

receive the endorsenent of the President.

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ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX A

MISCELLANEOUS FUNDING SOURCES

?CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

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APPENDIX A

MISCELLANEOUS FUXDING SOURCES

PATENTS

Towards the generation of funds it is recommended that duly

concentrated effort be dedicated to the development of Center

policy relevant to the Licensing of patents in eneray and envi-

ronment. If necessary, the policy could extend to all units in

the UPR System with the obvious benefits which would accrue from

inventions resulting from the projects financed by the UPR and

CHER within it. Because there are potential patents in on-going

work, it is suggested that the patent study begin as soon as

possible in order that the economic benefite may be promptly

realized.

?PUBLICATIONS AND DATA SERVICES

As a further revenue generator it is recomended that the

possibility of establishing a Publications and Information

Division be explored. Offerings for public sale would include

tens in Education, Research and Service in the fields of Enersy

and Enviroument, The publications would be available in Spanish

and English with selected itens in Portuguese and French.

Ip addition to publications a service could be offered in

providing ba

je data in Energy and Environment to interested

parties. In the past data related to solar applications has been

requested by domestic and foreign corporations holding contracts

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with private industry or government agencies. Direct and difuse

radiation data collected in our measuring stations has been

requested and provided without charge. The companies using the

aa

charge their clients for this service. It would seem
reasonable that @ policy for recovering costs to the Center
could be implenented. In similar fashion it would be possible
to recover the cost of publications such as those pertaining to
solar applications for donestic solar heaters from which there is

an obvious benefit to the consuner.

INDUSTRIAL LIATSON PROGRAM

As part of ite design for continuity and development CEER
has established an Industrial Liaison Office. The function of
this office is to provide essential services to industry in

supplying information to prepare reports on the state-of-the-

art in pertinent fields, organizing conferences and syaposia,

and various other services. Interaction between industry and

the University,long discussed but short on actual exchange of

?meaning between the two promises soon to be a reality.

?An analysis of counterpart activities at leading Univer:

ties on the mainland suggests that the Massachusetts Institute

of Technology (MIT) Model is the most appropriate. Discussions

have already taken place with MIT and CEER personnel participating.

Mo relevant obstacles are anticipat

im putting the program in

?operation. Revenue generated by the program will lessen the

financial burden of the Center.

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ENERGY AND ENVIRONMENTAL PROBLENS IN PUERTO RICO

APPENDIX 5

?PROPOSED LEGISLATION

(CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 April 1979

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APPENDIX 8

?A BILL FOR APPROPRIATING FUNDS FOR THE

CENTER FOR ENERGY AND ENVIROWENT RESEARCH

UNIVERSITY OF PUERTO RICO

STATEMENT OF MOTIVES

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

?Anong its current projects are the development of solar photovoltaics,

?ocean thermal energy conversion, use of sugar cane hybrids as biomass

foel, bilharzia control, effects of industrial developments and popu-

lation growth on land masses, ete.

The Center's principal objectives:

1+ To serve as the focal point for energy research in Puerto

Rico, in order to achieve energy independence.

.- To help Puerto Rico develop the scientific engineering and
other trained personnel neaded for the future in the energy eaviron~
ental and related fielda.

3+ To continue research and training prograns in environmental
sciences and technologies.

The Center for Energy and Eavironsent Research of the University

of Puerto Rico, evolved from the Puerto Rico Nuclear Center, established

by the U.S. Atomic Energy Comission in 1957. The Nuclear Center vas

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operated by the University of Puerto Rico for the Comission until the agency was superseded by the U.S. Energy Research and Development Administration (ERDA) in 1975. The Nuclear Center trained more than 2,000 students in nuclear sciences, engineering and medicine. Now the Departuont of Energy is funding CEER through a contract with the University of Puerto Rico, This evolvenent has given CEER the required expertise and modern available facilities. At present the CEER has under study or developsent nore than forty (40) principal projects related to energy conversion and or conservation.

The current energy crisis vhich is caused by a world energy shortage is expected to get worse through the remainder of this century.

Puerto Rico, with ite total

pendence for energy on imported fossil

fuel, is particularly vulnerable to dislocations in the global energy

market. This is an anomalous situation as there are few places in the world so generously endowed with natural energy: solar radiation, ocean temperature differential, wind, waves, and currents, all potential non

polluting pover sourey

CHER has been doing soue projects in this respect using the funds allocated first by the ERDA and now by the Departaent of Energy using the present available facilities which are capitalized at approximately twelve million dollars ($12,000,000). ?These facilities are being transferred to the University of Puerto Rico bby the Department of Energy (DOE).

CEER has been operated by the U.P.R. under contract with DOE in

?which the latter funds all the operational costs while also allocating

eb

additional money grants for individual projects on @ competi: 8.
These projects are for the development of energy from natural resources
and also for the protection of the environment.

---Page Break---
In Septenber 30, 1981 the contract expires and thereafter DOE will
not cover the operational costs of the CEER and although the funds
obtained from grants on a competitive basis will continue they will not
be enough to cover all the expenses. Te is therefore, necessary that

the Legislature appropriate the necessary funds to cover the CHER

operational needs in order to continue the development of new energy
resources which will fulfi11 an urgent need for the people of Puerto
Rico.

For said purpose,

Be it enacted by the Legislature of Puerto Rico

Tt is hereby found and declared that the purposes of the

center for nergy and Environment Research (GEER) of the University of Puerto Rico are for the developnent of environnentally acceptable energy alternatives through research on new fuels to substitute for those sade from petroleu 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 Comonwealth of Puerto Rico.

2+ The prograns alzeady started should continue, and new projects and grants sought to perfor research and developrent is

already established, due to which it is necessary that the Legislature

appropriate the required funds to continue the same.

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

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

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

---Page Break---

= Taxes to be levied shall be equal to one and a half cents (30.015) per million BYU's (British Thermal Units) of calorific value or its equivalent for the first two fiscal year (1980-81; 1981-82); two cents ($0.020) for the next two fiscal years (1982-83; 1983-84); and two and a half cents ($0.025) for each fiscal year thereafter.

5+ The Secre

sry of the Treasury of the Comonvealth of Puerto Rico is authorized and directed to collect the mentioned taxes and to place the aus therein collected at the disposal of the Director of the CHER starting Joly 1, 1981.

6- ALL lavs oF parts of lavs in conflict herewith are hereby

repealed.

J This Act shall take effect ninety (90) days after its

?approval.

---Page Break---

[ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX C

TNNOVATIONAL ORGANIZATTONAL STRUCTURE WITHIN

UNIVERSITY OF PUERTO RICO

(CENTER POR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 April 1979

---Page Break---

APPENDIX ¢

?THE POSSIBILITIES OF ESTABLISHING AN INDEPENDENT RED

CENTER INTEGRATED WITM THE UNIVERSITY SYSTEM

Given both the history of GEER and ite current wode of operations, it is clear that it could, and does in fact, operate as a relatively autonomous arn of the University of Puerto Rico. While subject to general university policies and reporting directly to the Office of the

President, its routine activities and its relationships with other institutions are deterained by the Director and impleaented by the in-house ataft.

Under these conditions, it is worth considering the further benefits which would accrue to the UPR and the increased flexibility which CHER ?would develop if t wore to be operated as a quasi~independent Research and Development Center under a new corporate structure. This development ?would parallel the histories of sone well know institutions such as Acthur D. Lietle (Harvard), Southwest Research (University of Texas),

Jet Propulsion Labs-JPL (Cal Tech) and many others which are lesser known, These organizations had their inception as "Think Tanks" or

specialized university res

scch laboratories during World War II as

specifically funded operations and then evolved into independent research

Ingtitueions as their expertise and experience broadened and become nore

generally available while still closely related to their respective

wniversity systems. Under their independently operating corporate

structure their flexibility, responsiveness, and competitivenss has not

---Page Break---

only eliminated the financial obligation of the University to support

then, but has proven to be a valuable source of non-legislated funds

for the University as well, Because of its equity position and che

resultant representation on the Institution's Board of Directors, the

University still has a voice in the policy and operation of the insti.

tution.

GENERAL CONSIDERATIONS

Inplenentation Procedures

Prepai

stion of preliminary proposal and tine schedule by CEER

Sstablishnent of URP/CEER Liaison work committee to draft

necessary legal / University and adninistration steps.

Stepwise authorization by President, Univer:

a8 required.

ity Board, CHE

Establishnent of non profit corporate legal structure.

Organizing of Board of Directors

Botablishuent of CEER administration

?Arrange transfer or long term lease of CHER facilities for

UPR to CEER for UPR equity.

Eotablich CEER-UPR financial relationship.

eablich CEER-UPR scientific relationship.

Inplesentation Requisites

1

GEER base funding sufficient for 5-10 year minimun operating

level.

CHER competitive funding growing at established ra

UPR willing to develop this relationship.

ALL legal and university regulations allow impleaentation

oF can be nodified to fit the situation.

---Page Break---

ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

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[APPENDIX D

EXAMPLES OF ALTERNATIVE SCENARIOS IN

?ENERGY AND ENVIRONMENT

?CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

?UNIVERSITY OF PUERTO RICO

7 April 1979

---Page Break---

?THE ENERGY PROBLEM IN PUERTO RECO

Various efforts are being undertaken by a variety of organize

tone in the Puerto Rico Government in the pursuing of solutions to

the energy and environsent problens which are adversely affecting

Puerto Rico and its general economic welfare. Every effort tends co Provide sone degree of assistance to the solution of the enersy problen. Probably, as the Director of the Office of Energy has said, the final solution is not under one option, but on the sum of many ?options taken together. The efforts of energy conservation, for example, should not be underestinated as well as other progtans now

under consideration.

The

riousness of the energy crisis is now looming more closely and threatening the Puertorrican Livelihood, economics, health and every sector of the very Life and blood of the present civilization as ve know in the western world. It is, therefore, felt that an outlook with an agressive energy program with definite goals and objectives should be developed and pursued to bring forth Solutions in the shortest tine:possible but with known and calculated acceptable risks.

CHER studies on the econoay of Puerto Rico and the dynamics of population grouth predicts that in order to maintain neatly the

sane level of econonic welfare the electrical energy generation for

the year 2000 will be three tines the electrical energy generation

at present. This does not include technological developments which

---Page Break---

will tend to u

more electrical energy such as the electric cars

which are now being introduced in the world markets. Appendix E

"Long Range Forecast of Energy Needs in Puerto Rico? describes the

Model Used for the predictions. This Appendix is part of an energy

study being performed by CEER.

?The growth in electrical generation indicates that the Puerto

Rico electrical eysten will need to add roughly twice the actual

generation capacity before the year 2000 in order to keep just

spproxinately the sane level of econonic welfare. This statenent,

under the present serious prediction of increasing fossil fuel costs

and scarcity of fuel oils is rather alarming. An agressive program

to address the massive amounts of electrical energy generation

requirenents of Puerto Rico is required

s00n as possible.

CCEER PROPOSED PROGRAM

In order to positively address the energy situation CFER

Proposes, as en example, @ strong R & D progran on the following

alternatives:

1. orec

2+ Photovoltates

3 Biomass

4 Ethanol (Motor Fuels)

5+ Solar Steam

Specific objectives are set for each of these alternatives with

approximate etart of operation dates and schedules of required R & D

funds.

---Page Break---

Bach alternative is evaluated economically in the Puerto Rico

energy scenario, Fron the econonic 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.

The sumsaries of the scenarios considered, under a crash type

R&D Program heavily involving CHER, are shown in Tables 2 to6.

?he following traces out the salient points of the overall prop Appropriate detail 4s presented later in this Appendix.

?Table 2 indicates an approxinate prediction of the energy requirenents in Puerto Rico up to the year 2000. Under che present socio-economic structure and without a strong Rand D progran on alvemate energy sources, the fuel bill for Puerto Rico during the present 1979 year exceeds one billion dollars and the total bill for the rest of the century is estimated in 155.829 billion dollars.

Table 3A presente the mentioned exemple Progran of energy alternative objectives under a very tight schedule, only achievable by concentrated and coordinated effort between the various govern nent energy planning related organizations and in which CEER is the ain R 6 D researcher.

Teble 3B indicates the barrels of oil saved by the proposed

crash program example scenario

Table 4 illustrates the effect of the example energy alterna

tives scenarios propo:

1d in the totel fuel oi1 consumption of Puerto

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

---Page Break---

TABLE 2

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

UNDER PRESENT SOCLO-ECOHOMIC STRUCTURES AND ABSENCE. OF

?STRONG X AND D PROGKAM ON ALTERNATE ENEKGY SOUKCES

pt w ?) ©

MILLION BARRELS OF OTL,

INPORTS FOX Tre

wear | EIECTREGAE | GASOLINE | INGOSTRY] tora | yer raice | TOTAL cost

enency (1) | _¢ presen(2)| ¢ omeR(a) 4)" Sfp | (3 witrions)

s976 | 21.7 17.6 26.3 64.7

1977 | 23.0 Tez 215 62.7

1976 | 24-5 16:5 23:5 65.0.

1979 | 26.0 1.0. 35.7 66.1] 14.70 Toor.

soa [27:5 378 26-3 Tie7 | 16.76 1203.

1981 | 29.0 185 a7 75.2 19.17 1447

3982 {29.7 29-1 77-8 | 21.30 i704

1983 [31.8 30-5_[e2.2 | 25.00 2055

sor] 33-6 32.0 26.1] 28.55 2858

(ses [35s 33.6 89.9 [32.70 2939

3986 | 367 353 93.4 | 36.29 390.

i987] 37-9 a7. 96.9. | 40.28 3803

98a 42-2 36:9] 103.6 | 44.72 4633

1989 | 44.8 40.9] 108.6 | 49.60 3396.

1390 | 47-4 42.9} 113.9 | $8.00 6266.

7991 | 50-8 451 119.9] 38.75 7048

1992 | 53.41 a3 T2521 62.75 ase.

3993] 56.0 49.7} 130-8] 67-00 9295.

3994] 59.1} 52.2] 137-0. | 71-30 3736.

39951 62C 54.8] 142.8 | 76.50 70928

199665.) 37-5] 148-9. 61-12, 12078

3987 | 68.1 60:4 755.2] 86.00 13347

cs 63.4 1623] 9.15 14793

7999 7a 56.6 168-6 | 96.62 76230.

2600-| 77-6 ?69.9 [175.61 102.6 18016

TOTAL $155,829

(1) Statistical correlations between population and GP and between GNP and Electrical Energy Generation. correlation 99%. See Appendix f

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

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

(4) Fuel oft proces escalation indicated is approximately 1980-8

1985-91

14.32 /year;

LX year; 1990-95: 6.8%/year and 1995-2000: 6x year.

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TABLE &

POTENFIAL, "ENERGY. AD COST REDUCTIONS"

WER EXAWPLE SCENARIOS

aay roy ?) (6)

RSTO. REDUCTION RL FRACT_GN Te)

TELLION BARRELS OTE 30° pais DOLLARS (oF scenanros

\vear [10 SAVINGS ?SAVINGS ?SAVINGS OF

scenanzos rm scevanros| wri sceNARIos | TOTAL-wow SCENARIOS

s905_| 99.9 0.53 17.32 0.58,

906] 93.4 364 204-67, ee

3987] 96.9, 70:94 40 Te

1988] 103.6. 18.07 208 a

1969] ?108.6. 23.40 Tr 60- 2

1990] ?113.9, 33.77 1857 38

iea1_]_119.9, 33.77 11984 28

i992] 125.2 33.77 Bets aie

3993 [190-8 20:50, ERIC 238

1994] 137.0 44217, 3158 328

1995] 142-8. 52.88 aoa ae

1996] 148.9 0:04 42868 408

fiss7 [155.2 6638 3709 ae

1398] 162-3 73:35. 6886. a7

1995] 165.6 30-02 Tere are

[2000 [175-6 50.02 3,210 ast

lrorars| 2072.6 657.18 51,909.0 368

loose

108

---Page Break---

362 of the total dollar expenditures up to the year 2000 ie accom

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

naximum saving which could be achieved since it is predicated

under 4 very tight schedule and R & D crash program requiring inter~

agency coordination and cooperation.

Table 5 1lustrates a possible source of revenues to finance the R and D program, A fuel. tax for energy and environmental ?research and dovelopnent is proposed on all non-rensvable fuels consuaption in Puerto Rico, The tax proposed is based on BTU consumption and it fluctuates between 1.5¢ to 2.5e per million BTU. A gallon of gasoline contains sone 140,000 BTU, therefore, this would hardly add 0.2 ~ 0.35 cents to a gallon of gasoline.

?Table 6 illustrates the total CEER funds requirements for the exanple scenarios. The last to colums of Table 6 indicate the

suggested source of funding.

---Page Break---

a @)

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?)

?Year

si08 | 8

1900

1981

1982

1983

1980 saae [ss

985. 13-1 fae.

1986. Tie Lar

3987 32:89 [37

7388 12-63 [33

1989) 12,81 | 30)

1930) 32.02 [37

1597 72:92

1952 3.71

1993 73.35

7594 33.92

7995, 13:49,

7096. 13.32

397 13.32

7058 13.34

1399 13.29

2000 Tad

---Page Break---

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?The logic in selecting and setting the example scenarios has

been based in the information, experience, and knovledge generated from R and D programs being undertsken by CEER since 1976. The level of effort has been very low, at the level of 2-3 million dollars per year, 100% funded by Federal Department of Energy. This low

level of effort needs to be increnented considerably as has been indicated in order to produce semingful results. Eeonosie considerations and evaluations, potential capacity of the alternatives to meot the local energy needs and actual technical status and projections of the altematives were taken into considerations.

These can be sumarized as follows:

Tee (Ocean Thermal 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 eneray needs of Puerto Rico at some future date, Ocean dased or floating type of plants in the southem Caribbean sea will have practically no inpact on land utilization resources.

Te is estimated that an OTEC-10 (40 Mf plant) concept could be operational within 4 years. Preliminary economic calculations

under certain

sumption indicate PRURA could afford $26.2 million

dollars toward investment and the energy obtainable will be comparable

in cost to one 450 Mi coal plant located at Rincon with Flue Gas

Desulfurization. Tt is suggested that the Puerto Rico Government

contribute with the sane funds for research and development. The

a

---Page Break---

project is estimated in $300 million including escalation and interest

ducing construction. The Federal Government appropriation requirenent

dis $247.6 million. A risk analysis consideration indicates an accept~

able calculated risk for public corporation,

Coot calculations were performed for 250 Mii OTEC concept

operational by the year 1990-91 and is shoun to be 61% of the 450 Mi!

coal plant cost of electricity. from this {t is assumed that PRRA

?can then finance completely such concepts from there on.

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

OBER requested R & D funding are indicated.

PHOTOVOLTAICS - Photovoltaics systems produce electricity by
converting direct solar radiation into electricity using photo

electric cells. A large fraction of the energy is stored for use
during non-daylight tine, It is a complete static systes with no

?known adverse environmental effects, The concept has enough potential

to generate all the electric energy needs of Puerto Rico required by
the year 2000 but it will require 90,000 ~ 100,000 acres of Land -
enormous farns of solar collectors celis and electronics.

The objectives for photovoltaics systens are defined in the
Program, its econonics in the Puerto Rico scenario aasesed and the
R 6D fonds requirenents are scheduled.

The most aubitious objective in the progran is to have an

industrial park with cogeneration (steam for industries plus

electricity) of 250,000 kv capacity for early 1990's, CER experience

---Page Break---

on a small similar project being planned at present is of paranount

importance for the undertalcing of this major task.

?The economics of the project indicate that the energy costs will

be 48% of the cost of @ 450 Mi coal plant, without the steam cogene~

ration portion. When the steam portion ie added the economic attrac~

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

scenario by using higher costs than the most recent basic data cost

information, 1)

R&D funds need to be secured by CEER from the Puerto Rico Govern

nent for this project in the level of $40 million excluding advance

{6 assumed that the Federal Government will

qe

concept development

match these funds for a total of $80 aillion requirenents in R&D. A

consortium of private enterprises, PRNRA and Fouento is suggested for

the capital investwent.

BIOMASS ~ Biomass is practically an agricultural enterprise. Tt

consists of planning selected optimized species for mass production,

harvesting, solar drying storage, transportation and burning the bio-

was in a suitably designed boiler to produce stean to run the turbo generators that produce the electricity. Ae such, an electric plant fueled with bionass is not very different from a conventional fossil fuel fired power plant. Biouass alone can supply all the energy needs of Puerto Rico by the year 2000, but it will require 700,000-800,000

acres of land. One single 450 1 plant in operation by the year 1987,

operating at 75t capacity factor could supply 13% of the electrical energy needs. Approximately 55,000-60,000 acres of Land will be re~

quired to feed the plant.

?Uy Solar Hiectricity and Feononde Approach to Solar Energy-Holfgang Beles eal" Beate HURBHE PFoerem, Comission of European Common:

---Page Break---

?The principal and immediate objective in a biomass program will be to convert an existing sugar mill to handle 1000 tons of biomass

per day and determine the logistics, production, burning efficiency, transportation, ete. The size is equivalent to 62,500 kv electrical boiler and is large enough for extrapolation to 400-500 Mi boilers. Te economic analysis indicates that biomass ie the costlier of

the three alternatives, but still has @ good economical advantage

over coal alternative. The preliminary calculation indicated that the cost of electricity from bionass is 86% of the cost of electricity froma 450 Yi coal plant. Tnits favor, is the fact that this alternative will require the least expenditure of funds in RAD. Techno-logically it is the least risky of ali chree considered but is, of course, the most costly.

The principal objective is to develop the necessary data so that PRIRA can vithin 1-2 years incorporate, in its steam boiler bids specifications, enough data for specifying boilers to bum any of three fuels-oi1, coal or bionass, and have all the logistics developed to burn biomass by the year 1986-87.

ETHANOL (MOTOR FUELS) - Ethanol can substitute gasoline or can be blended with gasoline to fora a mixture as gasohol. Gasoline with 10% ethanol can be burned in motor vehicles without carburator modifications, For mixtures greater than 102 ethanol carburator

modifications are required.

?Te consumption of gasoline ia Puerto Rico during last fiscal

year was 658 million gallons, Consumption has been increasing at the

?

---Page Break---

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

nents of Puerto Rico for the year 1990 (assuming the growth rate ie

halved) is estimated conservatively in one billion gallons of gasoline

(equivalents to 1.67 billion gallons of ethanol). This could be

weeane planta~

produced with a program requiring 1,000,000 acres of

tion vhich is approximately 83 % of the agricultural land in Puerto

Rico, Cost are estinated to be competitive.

?The K & D program objectives include the modification of # sugar mill to process 4000 tons of green suger cane per day ?o produce approximately 6000 gals per day of ethanol and the extrapolation of the experience to larger industrial scale to produce IZ of the gas0-Line requiresents by the year 1990, The indicated objectives are based fon approval this year of planned pilot plant operations at the UPR-RIM Experimental Station and existing prograns of development of saccharun

hybrid spec

for increased yields. Total R & D Funds requirements fare estimated at 12-13 millions excluding advanced concepts developaents.

SOLAR STEAM ~ CEER has developed a highly efficient and inexpensive solar concentrator for producing industrial steam. A project is under~ way with Bacardi Distillers to produce solar stean at the Bacardi Rum 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 11% of the gasoline requirenents for the year 1990 in ethanol will require

approximately 1 million pounds of steam per day.

1s

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The program objective is to reduce the cost of ethanol (and

fe least 40% of the steam

the energy requirenents) by supplying

requirements of the ethanol project previously described with solar energy.

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

Te is estimated that the R § D funding requirements for this

project is $25 million excluding the development of advance concepts

and related material development.

Total Budget

The total R & D budget which will be required by CEER from the

Puerto Rico Goverment to agrossively attack all alternatives

4s indicated in Table 6 entitled Susmary Table of Total CEER

Funding Requirenents for Exanple Scenarios"

?The details and rationale of the proposed progran are contained

in the technical analysis vhich follows.

---Page Break---

APPENDIX D

?TECHNICAL ANALYSIS OF ALTERNATIVE ENERGY SCENARIOS

conrents

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contents

Ww,

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vin.

ETHANOL, (MOTOR FUELS)

A. Potential and Econosie Implications

B. Program Objectives

C. Rand D Funds Requirenents

D. Advance Concepts for Ethanol

E. Bavironmeatal Research Scenarios for Bthanol

SOLAR STEAM

A. Potential and Economic Tnplications

B. Program Objectives

C. Rand D Funds Requirenents

1D. Advanced Concepts for Solar Steam

E, Environmental Research Scenarios for Solar Stean

SUMMARY TABLE OF TOTAL CEER FUNDING REQUIREMENTS FOR EXAMPLE SCENARIOS.

SUMMARY TABLES

Table 1 ~ Reserved

Table 2 ~ Predictions of Puerto Rico Energy Requirement to the year 2000 under the same present socio-economic structures and under the absence of a strong R and D Program on Alternate Energy Sources.

Table UA- Schedule of Proposed Scenarios Progran Objectives

Table B- Possible Million of Barrels O{1 Saved with Scenarios

Table 4 ~ Potential "Energy and Cost Reductions" with Example Scenarios

Table 5 - Possible CEER Revenues from Fuels tax R and

D Law

?Table 6 ~ Total CEER funds Requirements for OTEC,

Photovoltaics, Bthanol and Solar Steam

Rand D Prograns

Page No.

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as

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ANALYSIS OF EXAMPLES OF POSSIBLE SCENARIOS IN BYERGY AND ENVIRONMENT

- orEe

A. Program Objectives

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

A 40 Mf plant should be planned so that extrapolation

to at least a 5-f0ld scale could be attempted in a

second generation plant. (10 Mi Modules as per OTEC-10,

DOE Progran). This plant could generate about 1.12

of Puerto Rico energy needs by 1985.

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

?A 250 M61 plant can be planned as an extrapolation

of the Demonstration Plant.

?The Demonstration Plant plus this plant can generate

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

3. Electrical Systen Addition on a competitive Basis.

First 500 MY OTEC Plant in operation by the year 1995

and additional 500 Mi OTEC units in the years 1977, 78,

and 79. ALL the OTHC units could be generating the

equivalent of 17:5% of the electrical energy requirenents

of the year 1999.

B. OTEC Heonomics in Puerto Rico Scenarios

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

few in 1978 dollars.

Te estimated cost of energy can be roughly figured a5,

follows:

»

---Page Break---

Investment charges

a, Project Investment

-$200,000,000

(60,000) (5,000) (*) ??

. Yearly Tavestment charges

at 10z cost of money ~ $ 20,000,000

cc. Yearly energy production

at 85% capacity factor ????-?----?- 298 x 10 kwh

4: Investment charges in mille/

ewe ? aaannnnnn-n= 67.1 wils/ivhr

Operation and Maintenance (OSM)

?The OGM cost of an OTEC Plant cannot be too far off the costs of an equivalent oil plant.

?The marine portfon, such as hull and exposed sea water parts vill require nore 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 same amount of manpower as the two (450 Mi each) of fueled Aguirre Unite thie would amount to approximately a staff

of 170 men. At an average

wry of $24,000 per man,
(PRVRA average salary fér power plants) the total staff

salary would 6:

(#) Feasibility Design Studies-Deep Oi1 Technology, Inc. Subsidiary

Fluor Corporation. Unpublished. February 1979.

20

---Page Break---

Total Staff Salary

170 x 24,000 ~- - $4,080,000

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

: operation) between total staff operation cost including

Five Gas Desulfurization costs has been determined by

CEER Studies to be 2.33. Using the same ratio:

Total 0 and M

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

06M costs in nilts/

lever 31.9

Fuel costs

?The fuel costs are estimated to be 0.0

Total costs

Desonstration Project-99.0 mills/kvhr

' 1978 dottars

1985 Total levelized o

This cost can be estinated by including escalation

and interest during construction and levelizing the 08M

cost during the plant 1ifetine. Assuning 7% escalation

per year, one year period plaming and contracting arcan~

. genents, 2 years design and 3 years construction, the

interest during construction and escalation factors can

bbe worked as follows: (Assuming @ straight Line cash flow

of construction funds):

?Wor escalation and Interest during construction considerations

as well as levelizing considerations, cost of money, ete, see

REPEREE, SPER aS ia PRR HO, SOBEL SH ComeReLLY ave

a

---Page Break---

PLANNING DESIGN [coNSTRUCTION

1379 19801982 1985

Escalation before construction = (1.0793

Escalation during construction = (1,07)1+5

Interest during construction = c.07) 15

Investuent Escalation and Interest during

construction ~- Total Factor = 15.

Operation Escalation at 7% /year between

1979 and 1985 ~ one = 1s

Levelizing factor for 35 years lifetime

at 10% cost of money in a St infl

tionary econoay yield a levelizing

factor of 1.75 (*)

Total levelized cost 1985

Investment charge

(1. 0.5)

Operation and maintenance

(31.9) (1.5) x 1.75

40 Yi OTEC Plant total levelized

we 184.3 mills/evhe

(#) For Escalation and interest during construction cones

?a5 well as levelizing considerations, cost of money, ete

Separate CHER studies (Base line costs of commercially available

energy alternatives in P. R. scenarios).

---Page Break---

Comparative Cost

?The above cost can be compared with 92.54 mills/tovhe

for a single 450 Mi coal plant at Rincéa with flue gas

Desulfurization, 35 years Life and operating at 75% capa~

city factor (the lover capacity factor Ss justified in an

economic dispatch competition).

If the investnent charge of the OTEC plant were 8.8 ?ills/kvhe the coal plant and the OTEC plant will have the same energy production costs of 92.5 mills/kwhr (total 1e~velized cost during plant Life); at 8.8 milla/kwhr the total yearly investuent charge will be $2.62 millions (85% plant capacity factor) which justifies an investment of §26.2 millions in terms of 1985 dollars for PRIRA (or $17.4 millions in terns of 1978-79 dollars).

IE the local Government matches these PRIRA fonds for the R6D and subtructure requiresents for a total contribution of $52.5 millions dollars (1985 dollars) from Puerto Rico, the Federal Government contribution to be sought is 267.5 willion dollars (1985 dollars).

The fund distribution under this schene could be:

* CHER Studies on Baseline Costs of Comercially Available Energy Alter~natives. The cost quoted needs revision for cooling water systen acceptable alternatives.

---Page Break---

(CONTRIBUTION IN TERMS OF 1985 DOLLARS

PRIRA $26.2 millions ~ (plant investment)

PLR. Gov, 26,2 millions ~ (RéD)

Fed. Gov. 247.6 millions ~ (plant investment plus

RAD)

$300.00 miltions

yerational

PRHRA 08M 23.70)

PRIRA Investment 8.8

Sub-total 92,502)

P. R, Gov. Investment

Total P. R. 101.3

Federal Gov. 83.0

Total 184.3

?The funds assigned by the Puerto Rico Government should

be mainly for RAD, substructure facilities, laboratories, and

operational RéD.

CD This should be, the marinus Fixed by contract.

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

plant discussed.

---Page Break---

Approxinate Cagh Flow of Funds for Deno Project

PLR. Cov. PRA ?OE

Year| Year Cumulative | Year Cumulative| year Cumm.

19 _ _ _ _

20 2 2 sor 6 sx} 5

oy as 2 10x 20 sz | 10

82 ast a2 10x 30 sx | as

83 16 38 sox 40 ast | 30

Ba 20% 7% 202 60 soz | 60

as 2 1002 soz 300 40z | 100

Jn terms of dollars the contribution to OTEC from the

Puerto Rico Governsent should be:

Year] 19807 i9el[1982 [1983 | 1984 | 1985]

dae

3

3.u1| 3.97] 3.93 | 4.09 | 5.26 | 5.86

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

TE the results of the Deno Project are satisfactory an ex
trapolation to build a 250 Mii plant can be made with a high
degree of accuracy. PRMRA can share a higher risk and the Govern-
nent also.

Ie is expected that such a plant would cost $1500/kw in terms

of 1978 doltars.

---Page Break---

?The cost, of such a plant would b

Investment charges:

2500)"

Wey CS)

and in term of 1985 dollars = 30.2 aille

= 20.1 mills

06M costs will be assumed to be twice the staff cost (1978

dollars.)

(9,506,000) x 2 = 10.2 milte/iwbe

SUDO) ETE CBS

?The levelized 1985 dollars will be:

(20.2)(2.5)(2.75) = 26.7 mils ewe

Total cost is 56.9 mills/kwhr.

This is much Lover than @ fossil plant. PRWRA can finance

it completely.

Risk Analysis Considerations (of Denonstration Plant of

?Objective No. 1)

Since PRKRA ie a public corporation, it has to operate under

sound economic policies in order to market its investment

bonds in the open bond market. Tt cannot invest in any ven~

ture without taking a calculated risk. The percentage of

investment funds assigned to PRWRA in the preliminary econo~

ic analysis presented here is 8.733% of the total funds.

+ Feasibility Design Studies ~ Deep Oi1 Technology Inc.Subsidiary

Fluor Corp. Unpublished. February 1979.

---Page Break---

If we correlate as @ 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 if the chances of success of OTRC are better than 8.733/100

the PRWRA is taking an acceptable calculated risk. We feel the

risks of OTEC success can be conservatively figured ox « 50/50

basis. The balance

'5 to be provided by governnent. We also

feel that the Puerto Rico government, in undertaking the same

risk as PRWRA, is taking an acceptable risk. It is promoting a

needed energy alternative vhich 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:

waring should be worked out with more time and funds

availability to CEER.

?Advanced OTBC Concepts

After the first OTEC plants becone operational RED funds

need to be secured for improvenent of the existing eabryonic

technology and technical problens which night arise.

?The foam GTEC concept under investigation by CHER should

receive more detailed consideration then. A yearly assignment

27

---Page Break---

6.9 tes se 18 wl) ab at fe

me pons fe 9 ot a0 en bp

SD eve eect ac pen

sons exes ran cee

in [uss [an [aw | na

G. OTH Environmental Research Scenario

?The primary environmental issues a

jockated with OTEC appear

to be associated with:

1, heat exchanger design

2. intake design

3. discharge design

4. working fluid design

5. general unit configuration

ALL the above impact upon the process of site selection. A

Schematic of the interrelation between the technology development,

?the development of needed, environmental information and

sconomic/

ssthetic consi

lerations is presented as Figure 1.

Tt is assumed that the funds for environmental research are

included within the allocations already mentione

28

---Page Break---

PIGURE 1

OTEC ENVIRONMENTAL PROJECT

?OFEe ?ENVERONMENTAE ECONONIC/ AESTHETIC

TECHNOLOGY INFORMATION (CONSIDERATIONS

DEVELOPMENT NEEDED

1. Heat Exchanger | Biofouling Potential | Fouling influences

Design of different configu-| efficiency, control,

rations, materials | methods cost

?and modes of operatii

?Toxicity of control | Potential reduction

treatment in fisheries

Intake Empingement potential | obstruction reduces

Design efficiency

Entrainment potential | Potential reduction

of biotic stocks

reduction of fisheries

Discharge Field effects of Redistribution of

Design different plankton reorientation

Configurations ana | of fish

operations Alteration of primary

Influence on productivity-Food chain

currents alterations leading to

Influence on ele- | alterations in fisheries

mental distribution

Influence on tempe-

ture

Bioaccumulation of heavy|

metals in food chains

leading to man

4. Working Fluid | Field effects of Direct human injury

Design leakage

?Acute Direct kill of organisms

Chronic Toxic or stimulatory

effects,shifts of comu-

nities, losses of economic!

: species, losses of

aesthetically important

FORMS - impact on tourisn|

---Page Break---

IL. Photovoltaics

A. Program Objectives

1, Small scale demonstration (162 Wi) project to be located

at CHER.

This small project will provide know-how to deal

with this new technology and will develop greatly needed

?human resources to tackle larger projects.

Project operational by mid 1980. Data gathering there~
after.

2, Blectric Power Installation in the higher insolation
?areas of Southwestern Puerto Rico to provide 250 si
photovoltaic installatiof by the year 1993 and an ad-
dition of 250 YW photovoltaic plant capacity by the year
1993,

3, A cogeneration project to develop pover and steam in an

industrial park with the photovoltaic plants.

B. Photovoltaic Beonomice in P. R. Scenari

1. Storage Criteria for P. R.
Te is assumed chat 1/3 of the energy output of the

photovoltaics during daylight tine (B hrs) will be deli-
vered directly to the load and 2/3 of the energy gene~

rated during the sane daylight time period will be stored

?lote: The KW power value indicated are on a 24 HR continuous rating (storage included). Assuming an average of 8 hours insolation in the 24 hr. daily cycle, the eolar plants vill have a peak capacity of three tines 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 hrs, The charging rate ca?

pacity of the storage systen will be, on an aver:

basis, twice its delivery rate, This provides an oner~ gency "spinning" reserve of three times the continuous rate capacity of the photovoltaic installation for the electric utility, since the storage aysten can be dis~ charged at the cane rate as its charging rate. Credit for the extra "spinning" reserve capacity can be credited at the rate of capital cost of a conventional gas turbine. To take care of absence of solar radiation during rainy days and overcast skies and storage system mainte

nance problens a 25% additional energy storage will be

provided.

At an efficiency of collection and production of 4.5%

and aver

insolation pover of 7 KW-hr. per square meter

per day, the required area for producing 1 KW of conti-

?nuous power is:

3x ___ 8 exter = 76.2 2

os)

---Page Break---

The average insolation power per square meter is

1/24 or .292 kee per sa.

per 24 hour das

2, Investment costs

The cost of a photovoltaic installation can be

approximated by the following relationship:

Plant cost $=

w Wane ai) Cinsolation paver

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

co iw

?The following value are assumed from the present

day technology and extrapolation of the sane.

1977 dollars

(> Total array efficiency = 4.5%

(2) Array cost

Solarceil cost!) 4): 1,0 mill/ea? or $10.00/a?

Wiring,

eructure,

installation cost/s? $10.00)

Total array cost: $20.00/a2

(3) Storage cose per tah $25

(&) Power conditioning cost per kx: $50

Plane Costs

0, 0.250256) + 50

(045) (.292)

= 1522 + 500 + 50 = §2072/kw

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

' reserve capacity, but will be neglected.

?G) Coste of GS]at predicted by Unesco for 1993.

(2) Sane as cost predicted by Unesco.

(3) costs of $20.00 per ka-hr predicted by Unesco. Solar electricity and

economic approach to solar energy-wolfgans palz energy development progran

Commision ?of European Communities Brussels. UNESCO 1978 3

---Page Break---

3.

3.

Land and land rights charges:

The area for the plant (at a rate of 76.2

per

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

be assumed at $2000 per acre the land cost ie $10,000,000

Total Plant Cos

Plant: (250,000) (2072)= $518 x 108

Land: 5,000 acreas a 2000 _10 x 108

see 108

Investment charges in mills/kw-he.

?The scheduled and forced out:

rate for photovol~

taies must be lover than for an OTEC plant, for which

an 85% capacity factor has been assumed. We feel that

three weeks outage per year for photovoltaics is more

than adequate, for forced and scheduled maintenance.

This yields 94% capacity factor.

?The investnent charges at 102 cost of money and 94%

capacity factor will be, in terms of 1977 dollars,

Tavestments charges in mills/kw h.

= 28) G1) 108

= $.026

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

26 mills per lah.

28M Coste

06M costs will be figured on the basis of an ascuned

33-34

---Page Break---

plant staff, The area? per Xf of plant power is 76.2 22, therefore for a 250 YW module an ares 4760 acres is re~ quired. Such large farm electronics, wiring, ete. will undoubtedly require sone personnel, The following is ?assumed:

1 Superintendent

2 Asst, Superintendent,

2 Secretaries

5 Shift Supervisors

10 Shift operators

2 Electrical Engin

4 Blectrieians

2° Blectronfe Engine

4 Electronic Technicians

1 Tnserument Eogineer

4 Tostrument Technicians

1 Mechanical Engineer

3 Mechantes

2 clerks

2 Sanitors

5 Gardeners and general Landacapera

20 Security men (4 guarde/shifes)

5S shite chaufters

35

---Page Break---

1 Chauffer (regular hours)

3 Utility men (general)

2 Chemical Engineers (storage systen)

8 Assistant Chemist (storage «

tom)

1. Warehouse (spare parts) supervisor

2 warehouse clerks

1 Accountant

1 Purchaser, estimator

1 Clerk,

93 Total

?Ave. salary per man $24,000

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

?Assuming a factor of 1.0 for material replacenent,

ete., (and we believe this to be

very highly conser

vative assumption since photovoltaics is a static system).

Year Total OM $4, 464,000

mills/ew = 4,464,000 = 2.1 milis/kwh

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

Total costs:

Iavestaent 25.00

0.

© and M

Total (1978 dollars) 27.1 mills/kwh

---Page Break---

1985 Dollars Cost (sane factors

for OTEC Concept)

Total escalation for Tavestment (1979-1985) = 1.5

?Total Eecalation Factor Salaries (1979-1985) ~ 1.5

levelizing factor for Plant Life for Escalation of

0 M=175

Investment: (26) (1.5) 39.0

Operation (2.1) (1.5) (1.75)

wer

?The cost of an equivalent coal plant is 92.5 mille/ih

(450 Mt coat plant). The photovoltaic concept cost of

energy is 48% of the cost of @ 450 Mw coal plant.

The project should be suitable for comercial financing.

The cost of the plant itself, estimated at §2072/iw can be

twice or higher in cost and still the plant will be compe-

titive with coal.

Cogeneration Photovoltaic Project

+ The economics of photovoltaics locks very promising in

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

a very large area a pover plant site needs special conside-

ration. An industrial park can very well be developed adj

cent to the photovoltaic plant where process steam is produced

during the daylight hours from waste heat of the solar col-

Jectors and backed up with oi1 fired boilers or bionass fired

boilers during the night hours. Such a system will offer

---Page Break---

?great economical incentives to industry. The magnitude of

this project will require detailed research which is being

performed at CEER on photovoltaics and waste heat collection.

2. Photovoltaic Cogeneration project cost estimate.

a, 250 MW Power Plant Cost $467 millions

b. Cogeneration Cost Estimate (for evaluating level

of R&D funds requirenent only).

About 4 KW thermal power is produced for every 1.00 KWE

produced in the CHER 150 KS cogeneration project under

consideration. A steam flow of 2,122 Ibs/hr. at 220°F with an enthalpy of 765 BTU/f is predicted together with fan output of 151 kve. There is no condensate return in the CEER project. For a large co-generation project, condensate will have to be returned.

Assuming 10°F condensate (obtainable with sea water once thru condenser) the anount of heat that can be extrac~ted is approximately 900 Btu/Ib of steam. This is equivalent to 12,600 Btu/hr. of thermal heat delivered per kv-hr. of electrical power generation.

The total amount of heat that can be delivered in a Large co-generation project of 250,000 KW will be 3.15x109 Beu/ar. (ote that the 250,000 KW is the ave. 26 hr. daily

generation, The plant peak pover capacity is three tines

---Page Break---

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

8 brs. of daylight).

?Ae 80 capacity factor of the steam portion, yearly ge-

eration in thermal heat is 2.2 x 1019 Beu/year. Figuring

conservatively $2.00 per MUBtu steam cost for @ competitive

project total gross yearly revenues are $44 million dollar:

?The cogeneration project level of investment will there

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

For any such project the R&D funds are figured at 62.

?A level of $50 millfon dollars will be required for the 86D

of auch a project. Since the project is predicated under

fan economical basis, electricity being nearly half the cost

of a coal plant, and steam cost much lover than from ofl

fired plant, the project can be funded by finantial enter

prises on a comercial venture with PRWRA, Fomento

and the P. R, Government. The project could be in operation

by 1991-1992.

Te Se assuned that the P. R. Government can contribute with

50% of R&D Funds and the Federal Government with the reaaining

soz.

P. R, Governsont assignment to this project is at a level

of $25 millions (1979 basis).

---Page Break---

>.

?The funding distribution is estimated as follows:

Research Funds for Photovoltaic Cogeneration $105

Year B. R. Funds

Escalation Actual

79 - _ s10®

1980 50 1.08 38

1981 -70 ay at

1982 1.00 1.26 1.26

1983 2.00 1.36 2

1986 4,00 1.59 5.88

1985 5.00 Lm 7.95

1986 5.00 1.85 7.40

1987 4.00 2.00 4.00

1988 2.00 2.16 1.62

989 2.33

25.00, 40.73

Advanced Photovoltaics Concepts RED

R&D funds for advanced concepts and material research

a5 well as inprovenent of existing operations facilities

should be allocated at least at the level of one million

dollars yearly (1979 bas

) beginning in 1987, When esco-

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

---Page Break---

the following is the net result:

ADVANCED PHOTOVOLEATCS CONCEPT FUNDING ($ W311

ser 1988 1991990

1.85 2.0 2s 2.33

Environmental Research Scenarios for Solar Photovoltai:

?The primary enviromental questions arising from this

technology have to do with:

1. site selection, given areas of land involved and

2, the actual construction effects on the sites.

?The Firat question requires research by resource economists

and 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 ie primarily

of the nature of an Environsental Impact Statement and

ight properly be subcontracted to # qualified industrial/

cavironsental engineering fira,

Te ds dieficult to eatinate the costs of environmental

research efforts required, but it will be assumed that

such costs are included within the allocations indicated.

a

---Page Break---

TIT, Bona

A, Program Objectives (In addition to actual progran of

species identification and production optimization):

1, Design, construction, and operation of a pilot boiler

plant with a capacity of 1000 tons of biomass fuel per

day achievable by modification of an existing sugar

mill, Project can be operational within 12 months
after initial authorization, including the collabora:

tion of the PR Department of Agriculture and the

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

2. PRWRA shall be ready to request bide for 500 M6! stean
boilers suitable for bumning any of three fuels (coal,
of1, oF biomass) by 1981 oF 1982, and have an operatio-
nal plant ready for 1987 or 1988. Additional unit
could be operating in 1989, A 500 M plant operating
?at a 75% load factor will supply 10.7% of the energy
needs by 1990.

3. Routine considerations to be given by PRYRA, under
available technological know-how and market conditions,
for evaluation of biomass on competitive basis with

other available alternatives for future electric systen

---Page Break---

additions beyond year 1990,

Bionase Economics in

Scenarios

1. Pilot Boiler Plant: It de estimated chat a two-year

project denonstrating a 1000 tons per day pilot boi-
er plant, operational on @ 12-nonths basis, will

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

the investment will be in the bionass production phase, with special reference to off-season biomass production during a d-nonth 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 Departuent 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 systems with pusp and diesel engine installations ($380,000), and purchase of bionass harvesting equipment ($250,000). The Departnent of Agriculture budget i 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 estinated to

be $3.9 million. Continued production and operational

---Page Break---

2.

charges for years 3, 4, and 5 will total $2.05 aillion. Tais project will provide industrial-scale data

incident tot

a, Biomass production

1b. Logistics of biomass harvesting, drying, storage,

transportation, and incineration

ec. Logistics and costs of bionass-delivery technology

4. Furnace performance and design

Since the pilot project cannot be evaluated under
& competitive economical basis its costs will be added
to those of a comercial project identified under pro~
gran objective to. 2.

Large Scale Plant Project

Calculations for a 450 Mi plant will be made in
teres of 1985 dollars in order to compare with « eimi-
dar coal fired unit.

Cost of pover plant to burn coal and bionase

a, Investaent chargs

Coal Plant: $683/lur (1978 dollars)

Biomass plant:

A credit of $28/net kw can be given to the biomass

plant for the unneeded equipnent to burn no sulfur

foel but at the came time additional requirements

4a

---Page Break---

will be necessary to burn both coals and biomas

the sane boiler. It is ascuned these two costs

cancel out. The cost of the bioma:

burning plant

yuned to be the same as the coal plant.

Biomass pover plant $683/kw (1978 dollars)

Investwent charges same as for the coal plant 1985

@ollars.....23.2 mills per wh. (CEER energy

studies).

>. Fuel Cost

?The fuel costs for bionass has been figured at $25(1) per ton delivered with a heat content of 15,000,000 BTU per kon. This yleld $1.66 per nillfions Beu delivered fuel cost (Alex Alexander information). This cost is taken as 1979 fuel cost.

?Assuming the sane carrying charges for a bioma

stock storage of 3 month as was assumed for coal,

the carrying charges in biomass is 1/6 (1.66) (.1)

or 4 cents per million BM. The fuel costs at

1979 dollars level is therefore $1.70 per BTU

including 3 month stock storage charges.

?Gy This Tnclude $1900 par ton production cost and $6/ton transporta~

Drying of biomass will beon the field, cut and scattered.

Bales or bundles are truck transported from the field to the electric

power plant storage pile.

---Page Break---

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

1985 Fuel Cost = (1.70) (1.0725)6 MeBTU

a

Levelized (35 years) cost!) = 1.75 (2.59)=$4.52/m1U.

With a plant heat rate of 10,000 Btu/iwhr (at 75%

capacity factor).

°

Levelized fuel cost is 45.2 mills/per-nr.

operation and Maintainance of the bionat

operation

will be taken equal to 2 coal plant less the operation

naintainance of a FD Systea, This estimated cost

for O8t of Desulfurization System for coat plant ?)

is = STR (401 + 10Pgq) (LP) (1 +)", wher

S = sulfur content of coal 2/100

Py = price of Limestone $/ton

TR coal firing rate tons/be.

Raq * price of sludge disposal #/ton

LF = plant coal factor

= escalation

Y= years between tine of estimate and beginning

of operation.

?(See CHER wergy study. For levelization theory. This takes into

account rising costs during plant life.

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

dry sludge. This

tons of wet sludge, which requires disposal.

is combined with 5 tons of water to produce 10

---Page Break---

Using the same figuré

for the coal CEER plant study:

PL = Pyd = $5.50/ton

8 = .03

Te = 200 tons/hr.

LF = 75%

Y= 7 years

e = 08

Substituting above figures in the formula gives, OM Desul-

furization Plant = $5.2 x 106/year

The equivalent:

06M cost in milie/kwh

tor Pop systen) ig

5.2 x 108 1.91 milis/ewh

(414,000) (75) (8760)

The levelized 35 years OM for FOD System

Leverizes © om cost FoD = (1.91)(1.75)= 3.35 mills

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

determined at

? 3.3

ess ??-?-???? 3.3

cost O&M Biomass plant = 12.0 milis/kw

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

414,000 ew.

(2) The factor of levelization of 1.75 is derived in other CHER studies.

It levelizes the effect of increasing escalation of operation and

maintenance during the life of the plent.

a

---Page Break---

Total cost for Biomass plant 35 years levelized cost.

1985 doltars is:

Tnvestaent (sane as coal plant) 23.2

Fel 45.2

osm 12.0

Total (Biomass fired plant cost) 80.4 mills /ne

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

If the 80.4 mills/kshr is corrected for the investaent of

6.00 million (escalated) research funds invested in objec~

tive aunber one the correction is rather small. This

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

?more than recoverable in the program. In addition the

multiplying factor in the Puerto Rico economy of a billion

dollars reinvested in local fuel of biona:

versus ?coal oF ofl

more than pays for the project.

The second and third objective of the program can etand

fon its own economical basis.

©. Energy Research Funds Requirements for Biomass(1)

197919803981 398219831984 98s

1979 Base 2.0 50h 4

Becalation 1.0 1.08 17126296 1.47 1,59

?Actual 2.16 0.59 0,500.54 «59,64

(2) Late revision by Dr. A. G. Alexander indicate mall additional total

funding requirements in the order of $930,000.

---Page Break---

Advanced Bionass Programs

For the development of advanced programs such as flui-

ized bed systens, pelletizing, cycle inprovenents, tech-

nical difficulties of developed methods which needs impro-

venente a yearly assignment of 3/4 million in 1986 and

$1 million thereafter is allocated (1979 basis). When

escalated at 8X per year the resules is:

ADVANCE BIOWASS PROGRAM DEVELOPMENT. (MILLIONS §)

198619871988 19891990

185 2.00216 2.33,

Environmental Research Scenario for Biomase

The primary environsental issues associated with bio-

?nase fuel include:

1, Atmospheric emissions quality and quantity and poten-

tial toxicity to humans and other biota

Residue disposal including possible beneficial uses

of the ash as soil anendnents.

Secondary environsental research which ought to be pursued

is the possible coupling of sevage and other vaste disposal to

the rearing of bionass 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

fas in the case of photovoltaic generation.

Te is difficult to estimate the cost of the research

program for a biomass progran. However, it will be

sumed that such costs are factored within the allocations

indicated.

IV. Eehenol (otor Fuels).

A. Potential and Rconomic Implications

Gasoline consumption in Puerto Rico during last fiseal

year (1977-78) was 678 million gallons. Gasoline con

?sumption has been increasing and is presently increasing at the rate of 6,62% annually during the last twelve (12) years (1966-1978).

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

?The equipment and facilities required are existent in Puerto Rico and they will require relatively onal] invest~ ents for conversion.

Cane juice is extracted by conventional sugar cane mil~ Ling tandun, Juice is clarified in existing sugar mil1

(i) Office of tneray data

(2) Sugar crops as a source of fuels - DOE - 1978

---Page Break---

clarifiers and rotary vaccum cleaners and concentrated to bout 20% cotal sugar content. From this step on a ao-dification is required to the sugar mill, This modifica tion involve yeast fermentation of the concentrated juices (formentation can last 12-18 hours) and distillation of the sane.

The cost of additions is in the order of 10-15% of the

investment cost of a sugar mill.

In the sugar industry, bad weather or rain is a 4: to the sugar sucrose yield which reduces the revenues of the farmers. This is not so for alcohol production, and

fon the contrary it will be an as

?The production of ethanol from sugar cane and of elec-

tricity from the sugar cane bagasse conbined with the uti~

Lization of cane wae

is a very attractive program.

Ethanol yields today from sugar cane is 15.6 gallons

per ton of green sugar cane. Today the average production

of sugar cane in Puerto Rico is approximately 28 tone per

acre. Alexander) has estimated that vith a program

partially optinized for biomass, yields as high as 29 tons

of dry biomass (116 green tons per acre) are obtainable

today. The ethanol yield would be 1800 gallons per acre.

Historically, experience has shown that yields under

?actual field conditions are auch lover than under controlled

?The potential of sugar cane a @ Renewable Energy Source for Develo-

ing Tropical Nations - A. G. Alexander se

---Page Break---

experinental facilities. It is therefore logical to

expect lover yield of ethanol per acre than the in~

dicated figure.

of this calculation ve will assume

For the purpos

1000 galions of ethanol production per acre with 65-75

green tons of sugarcane per acre and. 18 tons of dry biomas

In order to produce the sane gallons of ethanol

?equal to the same gallons of gasoline consumption last

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

However, because of the lover heat content of ethanol this vill be equivalent to only 60% of gasoline requi-

resents. In addition this plantation could produce the

total energy requirements by the ethanol plant and nerate 50% of all the electricity requirements for the

year 1982 by burning of baggasse. The acreage indicated

represent _50_% of the total agricultural Land in P.R.
The implications to the sugar industry and to the energy situation in P. R, could be very far reaching with uch @ potential program.
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 biomass for

electricity.

---Page Break---

3. Program dbjectives:

1, Selection of saccharum hybrid candidates for evalua-
tion in a combined production of ethanol and dry
biomass. The agricultural part of this progran is

under the direction of Dr. A. G. Alexander and eui~

table candidates have already been identified.

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

1979.

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

?Large Scale Operation ~ Goal for 1986

. Ethanol production to equal 11% © of 1990 ga~

soline requirenents. Investment cost for a new

(Q) Assumes growth rate is reduced from present 6.6% per year to 3.3% Per year. Total 1990 gesoline 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

are considered. Economics studies of both altern:

tives are required.In addition optimization studi

of ethanol for electric energy and electric cars

Scenarios need to be considered versus ethanol for cars

1¢ sufficient

Electrical generation with baga

to feed 50% of the fuel requirenents of 500 MMi elec

trical machine at 75% capacity factor (equivalent

to 10.7% of the electrical energy needs in the year

1990 as stated under objective number 2 of the bio

?ass progran), Investment cost equivalent to @

coal fueled electric plant, of $325 million

Tt was shown that the alternative of direct firing of bio-

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 vill be twice the value

inated for biomass alone, because

of the lover yields used.

34

---Page Break---

RAD Funds Requirements

?The estimated 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

179 Factor ?Millions

Year _$ millions Escalation Actual

1980 50 1.08 5h

asst 1.00 a7 Lay

3982 1.00 1.26 1.26

1983 1.50 1.36 2.08

1984 1.50 3.47 2.2

1985 2.00 1.59 1.58

1986 0.75 un 1.28

1987 0.50 1.85 93

1988 0.25 2.00 50

1989 0.25 2.16 3h

1990 2.33 258

8.50 12.64

---Page Break---

D._Aavanced Concepts for Ethanol

Research for the production of ethsnol at lover costs

include increasing yield production, nev methods of fer~

mentation and distillation and nev cycle optimization methods.

Inprovenent of technical difficulties of the first ethanol

woh fund

plants will also require r For these purposes

1/4 million dollars is assigned for 1985, 0.8 million for

1986, 1 million for 1987, and 1988, and 1.5 millions for

1989 and 1990 (1979 dollars). After escalating the indicated

allocations the following results:

?ADVANCED CONCRPT ETHANOL FUND REQUIREMENTS (ESCALATED) $ MILLIONS

1985 98619871988 198919

4 0.8 1.8520 3.26 3.5

E, Environmental Research Scenario for Ethanol,

The principal environmental impact of ethanol production

is anticipated to be related to the disposal of the rum slope

for "mostos? which are known to be toxic to marine life at

concentrations presently released. Research is needed to

determine ways in which the useful components in the mostos

may be recovered for their energy and/or nutrient (fertilizer)

value. This vould enable the forner waste to becone a by~

product.

---Page Break---

Solar Stes

A, Potential and Economic Implications

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

Other industries using steam could probably achieve costs reduction of @ larger magnitude,

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

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

---Page Break---

to large industrial type of installation.

?The proposed large scale ethanol facility in Section IV will require approximately 100 million pounds of stean per day. As~ suming a1 stean requireaents are produced by the solar radiation bout 1000 acres of surface vill be required to produce all the steam. Assuning a ut{lization of 67% of land a total of 1500 acres

will be required, It is not logical to assume full production
of stean by solar radiation, because the ethanol facility will
hhave to operate on a 24 hour basis. One third of the stean re~
quirement could be assigned to solar energy.

Tais vill 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
feat and sell the steam for half the cost of an equivalent oft
fueled plant ($2 vs $4 per 1000 pounds of steam)

2, Progran Objectives

1, Beonomical feasibility and optimization studies and
design to provide steam in the order of 33 million pounds

't day to an ethanol plant (producing 11.% of the gaso-
Line requirements by the year 1986).
2. Develop the RED Progra to make @ reality of such a pro~

Ject operational by the year 1986,

---Page Break---

3, Extend the technology for general industrial uses by the

year 1988 to the u

evel of 5 percent of industry ofl

requirenent for the year 1988 and 10% by 190-1995 re~

quirenents.

Rep Funds Roquirenents

?The RED requirenents are figured as follows:

ye

1980

1981

ase2

1983

1986

3985

1986

1987

1988

1989

1990

tion

Fad Grcstin

a 2

2 2

3 38

3 6

1.0 tr

20 38

5.0 8.35

2.0 3.70

3.0 4.00

1.0

a

14.60

59

---Page Break---

Advanced Concepts for Solar Stean

R6D funds will be required for materials improvenent pro-

grams which will result fro the operation of the first ins~

tallations, efficiency improvenent for greater yield per

solar collection area, ete.

?The escalated allocation for this program i

ADVANCED CONCEPT FOR SOLAR STEAM FUNDING (ESCALATED) ($ MILLIONS)

198s 19871988989 1990

8 185 20 2.16 2.33

Environmental Research Scenarios for Solar Steam

?The sane environmental considerations given to the photovol-

taies and cogeneration concepts applies to the solar steam concept.

60

---Page Break---

wt.

SSOWUARY TABLE OF TOTAL CEER FUNDING REQUIREMENTS FOR EXAVPLE. SCENARIOS

TOTAL CEER FUNDS REQUIRENENTS FOR

?TABLE 6 (Cole. 1-12)

0tEe, PHOTOWOLTATES, BIOWASS, ETHANOL AND SOLAR STEAM RAD PROGRANS

MILLION DOLLARS

igeo)s.a | St 2.16 St a 6.45

igi]3.97 8 239 77) 2 6.77

9e2|3.03, 1.26 250 1.26 8 7.33

1983|4.09 2.72 [sa 2.06 58 10.07

r9se5. 26 5.88 Tso 2.21 a7 13.38

1985]5.06 7.95 [6 139] 18 19.62

vss] Tul a | ize} sel ss | a

1987 1.85 {7.40 | 1.05 1s[93] as] 3.70 | 1.85

1988 2.00 | 4.00 | 2.00 2.00 | 50] 2.00) 4.00 | 2.00

1989 2.16] 1.62 | 2.16 2s] sf 3.26) 2.16 | 2.8

1990] 2.33 2.35 233 | _.se| 3.50) tay | 2.33

frats 26.2 |10.02 | 40.79 | 8.24 6.02%) 9.u| 12.64) mes) 25.62 | 9.16

(2) Assumes Federal Covernsent Participation in a ratio of 4.88 to 1.0, vhere the Puerto

Rico participation ie shared equally between PRIA and the Goverancat.

?Government

Funds? assigned for Research; PHWRA funds assigned to Capital Investaent determined from equivalency of coal plant goveration costs. (Escalation and incerest during construction included in estinate).

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

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

---Page Break---

VEL. SUMMARY TABLES

Cy

---Page Break---

ESTIAATES OF PUERTO RICO'S ENEXGY MEQUEREMENES 0 THE YEAR 2000

UNDER PRESENT SOCIO-ECGHONLC STRUCTURES AND ABSENCE OF

?STRONG R AND D PHOGRAM OW ALTERNATE. ENERGY SOUNCES

1 a o 6) ©

za@onrs Fou ESTINATED

vear | ECHUCA | casouime | ?TnoosTmr?] tora. | way parce | TODAL cost

peeny (1) | § OIESEL(2)| _¢ omen) i" fant, | (§ winisons)

s976 | 21.7 128, 26.3

i977 33.0 18.2 Fi

Tan] aes 6:5) 235

1379.) 26-0 17 25:1 Ta70 Too

yom [75 17:9) 36:3 16.78. 1203,

t38r| 29-0 78.5) a7 7 aa,

sear} 29.7 19:0) 23 21.30, 1704

soa [a3 13:5) 3035 25.00 2055

soa] 336 20.5 32.0 28.35. 2456

3985. | 35.5 0 | 33.6 33:70 23.

1986. [36.7 aa 35:3 3.29 3390

3907] 37.9 239 30.28. 3303

1906. | 4-2 Bas 46.72 635

1989. | 44-8 21 49:60. 3396

1990. | aa 26 35.00. e266

i991 | 30.8 3eo $8.75 oa

igor [5.8 63.75 7e56-

1993, [56-0 67-00 3295

1994-|?39.1 ne 3796

3995 [67.0 76:80 0894

1996, e112 13078

1987 16.00] 43347

3998 [71-5 S115} a7

3999 | 74st 96.62 | e290.

2000 77-6, 175.61 02.6 TeaT6

som, 315,829

(2) Statistical correlations between population and GHP and between GIP and

Hlectrical Eneroy Generation. Correlation 994. See Aupendix

(2) Gasoline Consumption grovth projected conservatively between 2.1/2 - 3%

per year vs. 6.62 actual. More accurate predictions to be included in

(CHEN Energy Studies

(3) Industrial needs projected at SZ per year growth. More accurate predic

?tons to be incluied in CEER Energy Studies.

(W) Fuel oft proces escalation indicated ie approximately 1980-85: 14.32/year;

1985-50: "117 year; 1990-95: 6-8E/year and 1995-2000: 6% year.

~ 6

---Page Break---

a

TABLE 34

SCUROULE OF PROPOSED SCENARIOS PROGRAM OBIECTIVES

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suscrie (1)

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SAIS

use. [ssenniosuos)

EARS] RY SSCA SIENT TON SAV

RELLION BBL OTL.

eofgas. reg.)

r

ROL PL.

137888

1985.

=e

7986.

1987

a

908

7985,

aoa

1950.

Taso

982

ro)

om | ST

re

3995.

ro

3996.

1398.

3=500%

1995.

= 50006

2009.

(2) At Least 9-500%M base Load units will be required in the period considered.

Daditiona} foe) forded Wits needs to be added,

TABLE 38

POSSIBLE MILLIONS BARRELS OTL SAVED WITH PROPOSED SCENARIOS

a @ 2) wo © © o, @

wear] omc | supra | eman | SFORASS | casonell erecerte(2)| saan | tors

x05] 53 0.53

7986 | 53) Tae 5.64

3987 | 53 Sacer |e 70.94

yee] ? 53 333

1999} 53 79.6

1990 [3.86 10:6. 33.77

3991 [3.86 10:6 377

3992] 3.06. 10:6) 33.77

3993 [3.86 [3.55 0.6

ig9a] 3.86 [3.53 10.6)

y995] 30.53 3.53 10:6. 32.08

4996 | 10.53 [7-00 10:6. 66-01

1997 [17.20] 7.00 10-6 66:38

ye98 | 23.64 7-00 70:6 135

1999 [30,54 [7.00 10:6. 0.0

2600-1 30:54 ?J-7.00 10.6 ?0.02

(2) Retimated 00 take per ton of (S18 moisture) baggese.

oe

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?ABE 4

POTENTIAL, "ENERGY axD COST REDUCTIONS?

?WER BXOMPLE SCENARIOS

a. 2 re wy 5 (6)

So ENT nLTON FRACTION TT

MHELION BARRELS OTE ??]_ 10° ous OLLARS (OF SCENARIOS

jrear [no ?WERE EXARLE | ? SAVINGS SAVINGS SAVINGS OF

Jsceuanzos | sceanros | wrm scmianios| win scenagros | TomAL-NoN SCENARIOS|

1905 | 09.9 99.37 0.53 17.33 oss.

1986 [93.4 87.76. 3.68 7487 a

a7 -96:9, 35.96 Wo:54 rn ae

985 [703.6, 35:53 18.07 oo ae

585 | Y08-8, 3540 23.40 Tr160 aie

1990] 103.9 3013 S377 11857 308

390 96.13 33:7 T1364 28

992 tas 33.77 zn 2

993 20:50. 24 2

983 ae 31138 ae

3995, S284 aoan, Sr

7996, 60.08 668. ay

3997, 66.38. 5,709, ae

1998) 73:35 6,886. ae

3999) 30.02 7732 are

2000 30.02 B20 a6

1435.62 657.18 1,909.0, 26

2

108 _.145,966.

---Page Break---

TABLE 5

POSSIBLE CHER REVENUES FROM FUELS TAX RED LAW

a @ o © © © @ @)

TAEELIGR [71-5677 Bo BeTOE wT 2A oe

BARRELS AX, 7x 7

year [CouSUNPTIOT

. with swe] oy s108] 8 5108 |

SCENARIOS

1900 | 71.70 6.45 10.53

1961 75.2 6:77 [0-47

1982 77-80 33a O35

7363] 82.20 4:86|0-48

1964 ?| 96:10 =r

3985] 09-37 Has.

3986] 27.76. =a

7967] 85.96. a7

1988 95.53, 33s

1969 85.40 330

1990_?[80.13 227

1991 [65.13 236.

1992 | 91-43 22a

3933 | 90:30, 2

7398 az

985. 20,

1996. ae

7957 a7

990] e895, He:

3999 | 68-58. aie.

2000 [95.58 a5

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[ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX E

?LONG RANGE FORECAST OF ENERGY NEEDS IN PUERTO RICO

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 April 1979

---Page Break---

APPENDIX

WONG RANGE FORECAST OF PUERTO RICO'S ENERGY NEEDS

ELECTRICAL ENERGY FORECAST

AL General

?the problen of forecasting long range estimates of enersy use is a rather difficult task because of all the uncertain= ties involved in the development of new technologies and

changing habits hich will affect consi

ably the estinate

An attempt has been made to forecast for a length of period in which present enbryonic technolgies could be extrapolated in a qualitative sense. A 40 year period, up to the year 2000, is believed to be long enough to provide for such an extrapolation and at the same tine provide energy planners with an overview of the next four decades for the adequate focusing of energy altematives

CEER interest is mainly in the energy or fuel alternatives

Scenarios which are required to power the Puerto Rico socio-

econoaic

velopment ; therefore, the forecasting has been

restricted to the total electrical energy generation which

responsible for the fuel consuned in the electrical plants

Classical statistical regression analysis were used. (1)

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

complicate the prediction with complex relations andhypothes

such as postulating saturation functions, ete.

GY Fase naaeE Sue EE Resisiog,tekigg, WA. chance 1969,

RATRDORSEY IADD., Hokeleton, Ontario?

---Page Break---

The prediction of energy generation requiresent is recognized

to be based on two main factors:

I~ Population

- Heonomic welfare or incoue per-capita of the population.

?The above factors were be analyzed statistically in

making the prediction. After the mathematical relationship

were established, then judgement of past experience and insight

of new technologies and changing habitswere considered £8

select the most appropriate relationship.

The energy prediction ves be based simply on a correlation

between total GP at constant prices and electrical energy.

The GNP ?was be predicted from the product of population predic~

tions, times the GNP/cepita prediction at constant prices. Popw~

lations have already been predicted by the Planning Board up to the

year 2000, GNP up to the year 1983. ur predictions will be,

therefore, somewhat uncertain for the period 2000-2020.

Be Population

@ Gaterene

Population is a very sensitive variable in the prediction of

energy needs. Different governments programs, economic velfare,

Social and religious groups? attitudes may influence to a certain

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

Browth rate of the economy of a nation responds better to a moderate

increase in the population, then to a rapid growth rate as is the

Present case concerning Puerto Rico, uhere population is doubled in

jobre Econoafa y Poblacién, Dr. Janes A. Santiago Meléndex

Serie de Conferencias y Foros: Nin. 4 Departamento de Econonfa, Universi
dad de Puerto Rico, Rfo Piedras, Puerto Rico.

---Page Break---

less than 35 years, or to a slow population grovth 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 econonie growth.

A rapid population grovth 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 growth rate on the other hand can create a problem as the population matures in age and there are not enough youth to replace those leaving the labor force. This has been experienced in certain areas of Japan. However, the concept of optinal population growth is difficult co 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 eity basis up to the year 2020 has been made.

?The population of Puerto Rico in 1960 was approximately one half of that predicted by the Planning Board for the year 2000, i.e. the predictions indicated a doubling of the population in thie 40 year period.

Using @ Linear regression analysis on historical population data, dating back to 1962, and the Planning Board predictions ep to the year 2000 as input data to the regression analysis in which the total nunber of input points is 22, gives the

following equation: yp = 2166.9 + 65.05 x

---Page Break---

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

fe, year less 1960, Coefficient of determination of above equation,

12 = 0,98, indicating a significant correlation of 99%.

The predicted population calculated in this sanner for? the year 2020 vill be 6,070,110. ?The approximate doubling tine of the present estinated population of 3,338,000 using the above Linear relationship is 51.3 year, This ie within the range satisfactory for an adequate economical growth as pointed out by Meléndez. An exponential regression of population vas also attempted. ?The exponential relation gave same degree of correlation and coefficient of determination as the Linear relationship but the doubling time of the present population was 35 years. Since this should not be the policy of government as previously indicated

it was discarded. The exponential relationship we

population

equals to 2308.66, times ?e" elevated to the exponent 0.02%, x

having the sane meaning as before.

The predicted population for the year 2020 with this

?exponential relation was 7,300,580, This was discarded in favor

of the more appropriate Linear correlation indicating « 6,070,110

population in the year 2020,

@

op. cit.

---Page Break---

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

TABLE 1 ~ POPULATION

BY LINEAR REGRESSION MODEL

?YEAR POPULATION (MILLIONS)

1979 3.47

1980 3.53

1981 3.65

1982 3.7

1983 3.78

1985 3.92

1990 , 4.26

1995 4.52

2000 4.67

205 5.08

2010 5.42

2015 5.75

2020 7

Beononic Welfa

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 noderate yearly increase. The total GNP at constant. dollars should then reflect a yearly increase of at least equal. to the population growth rate in the rate GNP per capita. The total GNP in current dollare should further reflect any increase due to the inflation price factor.

---Page Break---

The Gross National Product (GNP) sume up the economic activiti

of the country in terme of production of goods ai services, The total consumption of electrical energy by all sectors of the economy is very sensitive to this variable and can therefore be satisfactority corre

lated, Statistical tests can determine how good the correlation is

The Planning Board has predicted total GNP values in

current dolla:

up to the year 1983

indicated in Table IT below:

Planning Board Prediction (of GNP)

Current Dollars ($ thousands)

1979 1980 1981 19821983

Current $ 9835.0 10750 «11,693 12,710 13,795

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

Constant dollars were estimated by assuming a 10 percentage

points incresentt in inflation for the year 1979 and 7 percentage points increment for the renaining years, The 1978 inflation factor relative to 1954 (the year that the Planning Board used to reflect constant prices) is calculated to be 2.33 from the Planning Board reports on current and constant dollars data.

Using the predicted populations for the years 1979-83 the

above GNP in constant dollars were converted to GNP per capita.

---Page Break---

These data together with historical data back to the year 1962

were then retrieved by statistical methods. Four types of regr

sion analysis were tried, including, Linear, exponential, loga~

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

Lation coefficient or 95% coefficient of determination. This

fie was: y = 546.87 x°?7, wher

y = ONP/capita in constant

1954 dollars, x = year - 1960.

Predicted values with above equation indicate yearly impro-

vvenents 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,

?he predicted GNP per capita at constant dollare vas

multiplied by the predicted population to obtain the total

predicted GNP at constant dollars.

Electrical Generation

The total electrical generation was correlated vith the total

Results were as follows:

Coeff. of determination 98%; doubling

20 years

2) Power Correlation?: Coeff. of determination 9825 doubling

Time: 1 years

3) Log Correlation : Coeff. of determination 972; doubling

Tine: over 40 years

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

Tine: 5 years

---Page Break---

A statistical test indicated excellent correlations on all

the above.

Of all of the above correlations the log and exponential

correlations are discarded because of poorer correlations relative

to the Linear and power correlations and because of the very slow and very fast growth rates respectively. The Linear and pover regression analysis represent reasonable selection projections.

Blectric power generation has been doubling every 5 years

ducing the 1960 decade. During the present decade it has been doubting every eight years. 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 habite are maintained, It is felt however, that new Cechnologies and new consumer goods will impact

beyond present expectations on further needs of electric power. One

example, could be the development of urben electrical vehicles

requiring nightly battery charging. This requirenent might offset

the leveling of pover growth as predicted by a linear relationship.

?Also, the development of new technologies for producing electrical over from renevable sources (solar) aight bring down costs enhancing an increase in the demand. We, therefore, feel that the power fit represents an adequate description of future electrical generation production.

(0.012294) (ox) !+96 x 106

?The power fit is given by, KWIR gen

where the unit for GIP is million dollars at 1954 constant dollars.

---Page Break---

Table IIL indicates the correlation data for population, GiP ?nd Electrical Energy. The figures given for electrical enerey consumption are comparable to PRURA forecasts but they tend to be fon the low side. Power Technology(3) prediction for the year 2000 is 38,261 x 106 KWUR generation which is comparable to our Prediction of 42,910 x 10° KWHIR within 5% difference.

The prediction of electrical energy generation for the year

2020, shown in Figure 1, using the above selected relationship is

89,120 millions Kw-hr, which is slightly over six times the current

electrical energy generation. Energy plane

and researchers

ust, therefore, think of energy altematives for Puerto Rico in

4 scale a5 large as six tines today's demand by the time vhea

supposedly most energy alternatives being researched today could

be highly competitive economically. Electrical energy is used

round the clock, hence, large storage systens on direct solar

derived energy must be looked at in perspective.

?GD Tang Range Sales Forecasting Study for the Puerto Rico Water

Resources Authority, Kevin A. Clenents and Robert de Mello, Power

Technologies, Inc. Schenectady, N.Y. May, 1976.

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TABLE XT

(GNP POPULATION AND ELECTRICAL PRODUCTION CORRELATION DATA

CONSTANT PRICES (1954)

Fiscal Gur/capita Population _GNP_?Electric Prod.

Year S/Capita Thousands § millions 106 KWchr

a 694 2,228 7

63 736 23473 15

he 768 23523 22

65 817 2,568 2

66 861 2,603 28

67 892 25623, 7

6 927 2,650, "9

co 1000 23685, 35

70 1070 2m 25

n 1120 2,747 23

n 1139 23823 0

B 1186 23910 °

% Lies, 25991 23

5 a3. 3,078 23

1% 1103 3h167 28

n a6 31266, 4

% 1150 3,338 23

3 1166.48 3,470 : 12

80 1217.8" 3,530* 18 1542916

a1 1246.528 3,650" 16,307.2,

8 1294.1 3,720" 17119715,

85 1310.9 339208

30 1377's

95 1436.4

2000 1489.4

2005 1537.8

2010 1582.5,

2015 1624.0

2020 1662.8, 10,093.20 89,120

* elanning Board Predictions

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fon Making, W. A. Chance

Conferencia sobre Heononta y Poblacién, Dr. Jaime A. Santiago Meléndez, Serie de Conferencias y Foros: Nan. 4 Dopartanento de Econonfa, Universidad de Puerto Rico, Rio Piedras, Puerto Rico.

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

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APPEIOIX F

?PROPOSED PUERTO RICO RESEARCH INSTITUTE

(CENTER FOR ENERGY AND ELVIRONOGINT RESEARCH

. siveesrTy oF PUERTO RICO

8 sprit 1979

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?PUERTO RICO RESEARCH INSTITUTE

?The main porpose of the Tastitute is to serve the advancenent fof science and technology for the betterment of the Puerto Rican family and humanity as a vhole; szong ite main purposes will be the Aevelopnent of know-hov" principles and technology vhich will help local industry to develop and offer industrial products in the world ?market competetively and therefore advance econoaic welfare and standard of Living. The Institute shall be a non-profit research organization. Energy research shall be one of its main areas of concern. It shatl be incorporated under the lave of the Connonweelth of Pucrto Rico.?

?The Institute will provide specialized research and advisory services, by contract, to solve specific problene for industry, govern

ent, foundations and individual

?The Institute vill undertake pure ae well as applied research

Indicated above.

The Institute shall be formed by contributing mesbers mainly

private organizations, industry, professional organizations, ete., and
?the government. The greatest bulk of the research work is expected
0 come from Puerto Rican Government sponsored contracts on energy
Ferearch field for vhich adequate. cooperation needs to be obtained from

goverment by legislative action.

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The Institute will be regulated by a set of By-Laws approved by
its menbers. Approval and modifications of By-Lavs will require
endorsenent by 2/3 of Institute meabers. The Institute will be
governed by a five-nesber Governing Board elected freely by its
menbers. Governing Board wenbers shall be elected to serve for a
period of five years in a staggering order. The Governing Board
mesbers will be constituted as follows: President, Vice-President,
Secretary, Mesber and Monber.

Te Governing Board vill select its President, Vice-President,
?and Secretary between themselves. The Governing Board shall meet at
east once month.

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

?Any person of recognized moral standing and any organization

oF corporation doing legitimate busine:

can apply for menbership.
ALL Institute menbers will have a yearly dues of $500. A down Paynent of 50 years dves ($25,000) will make the menber a Benefactor Life Menber. A dom payment of 30 years dues ($15,000) wil make the member a Life Nenber. Organizations or Corporations menbers will have only one representative with voice and vote. Each active member will have only one vote.

Mesbership privilege include participation with voice and vote

on all Institute members necting. They will receive copies of all unclassified Institute research project reports. Short general consulation

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and orientation from staff meabers is provided free of charge, and

free use of Institute Library will be provided.

?The Institute will benefit from the menbership of certain Covern~

ment institutions. Adequate legislation should include incorporation

of these institutions as Benefactor Life Menbers ond authorization

for payment of dues. Such Government Benefactor Life Mesbers should

include:

?The President of the University of Puerto Rico

?The Chancellor of the University of Puerto Rico-Rfo Piedras

3. The Chancellor of the University of Puerto Rico-Mayaguez

Campus

The Chancellor of the University of Puerto Rico-Cayey Campus

The Chancellor of the University of Puerto Rico-Medical Sciences

6. The Secretary of Agriculture

Manager of Puerto Rico Development Administration

8. Executive Director of PRIRA

9. Direct Representative of the Governor

10. Director of the Office of State Energy Affairs

U1, Planning Board Chairman.

Each governsent menber indicated above will have one vote at nesbors meetings making a total of __11__voting monbers for the go-vernnent by legislative action, Other governnent agencies or institu-

tions could apply for wenbership on a voluntary basis.

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Government contribution by State Legislative Assembly authori~

zations must be sought for permanent facilties and laboratory equip-

nent. Some help on operating funds for initial operations may pro-
bably be required. All equipment and property bought with
Governnent funds will rensin property of the Government and will be
Sdentitied properly and taken care and disposed of as regulated by the
Office of the Controller. All direct work performed for the Govern
went will be by contract and such contract should reflect corresponding
cost reduction for the use of government property.

No official or menber or other party shall pecrue Financial
Benefit since this is a non-profit corporation. However, research

Projects shall be performed at cost plus sone Institute benefit to

provide for self expansion of permanent facilities purchase of addi-

tional Laboratory equipment, ete.

Te is expected that the majority of meabers will be from private

institutions and local industry.

Me menbers vill have an annual business meeting in the month

of Novenber and will appoint the Governing Board or whatever vacincy

there occurs in the Governing Board. No employ:

of the Institute

who simultaneously holds seabership in the Institute will be permitted

to vote in the selection of the Governing Board Neabers.

?The Governing Board will preside at the wenber nectings and dis~

cuss the affairs of the Institute including Financial, Technical, Research

-4e

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Projects, Topics, ete. At least two nenbers meetings shall? be heTd

yearly.

The Governing Board will appoint the Executive Officers. Exe~

cutive Officers will be employees of the Institute. They include the

President and the four Vice Presidents of the Institute as follows:

1) President

2) Executive Vice President-Contractual Relationships and Fund

Raising '

3) Vice President-tngineering and Research

4) controler

5) Personnel officer

?Tere shall be as many Divisions as found neces:

ry. ALL changes

in organizational matters have to be approved by the Governing Board.

?he President will appoint the Division Heads in consultation with the

Vice Presidents and with the er

jorsenent of the Governing Board,

ALL officers of the company shall be full tine exployees and

they will have a salary as approved by the Governing Board. No officer

can be renoved from office unless proven of misconduct, negligence,

inadequate discharge of duties, incompetence, ete.

AL research projects sponsored by public funds shall be for the

benefit of the government and the people of Puerto Rico. All research

Project carried with private funds shall be proptictary {£ so desired

by the sponsoring organization.

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ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX G

?THE NEED TO EXPLORE ALTERNATIVE ENERGY SOURCES FOR PUERTO RICO

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 Aprit 1979

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APPENDIX G

?THE NEED TO MAPLORE ALTERNATIVE ENERGY

SOURCES FOR PUERTO RICO

?DYTRODUCCION

La cusdruplicaci6n de los precios del petréleo por parte de
La Organizacién de Pafses Exportadores de Petr6leo (OPEP) a fines
el aio 1973 ha tenido un impacto profundo y permanente en las eco
nonfas de casi todos los pafses del mmndo ineluyendo a Puerto Rico
EL impacto inieial fue un fuerte aumento en los precios de casi todos
os Bienes y servicios internedios y los que van al consumidor final.
EL aumento de los precios aunenté los costos de produccién de casi
todos los sectores industriales reduciendo asf 1a capacidad productiva
de estos. La inflacién que fue seguida por una severa recesiéa av-
wnent6 1a tasa de desenpleo reduciendo 1a produccGn actual y aunen~
tando el "gap" entre esta Gitiaa y el producto potencial que se obten-
aria de 1a economia estar usando todos sus recursos a casi su capacidad
Se estima que e1 aumento en el precio de le energia redujo en forma
permanente 1a capacidad econSmica, 0 1a produceién potencial de la
economia de los Estados Unidos en cerca de un cinco porciento (1)
reduciendo tanbién en forma drstica la productividad del capital y
Ja mano de obra.

La produceién de un sector industrial, 0 de 1a econoufa en su totalidad, dependeré del acervo (stock) de capital, de 1a nano ée obra, otros recursos (como 1a energia) y de c6mo se combinan estos

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

are

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recursos (la tecnologia). Los precios que #¢ paguen por estos recur~ 09 determinan los costos de produceiGn. De tal forma que el aumento fen e1 precio de energia afect6 los costos de produccién (dada la tec~ nologia) 16 cual tuvo wn impacto adverso sobre 1a producciéa. En cummto se afectaron:los costos de produccin va a estar determinads

por 1a participacién ("share?

gel recurso (el cusl fue objeto del

aumento en precio) en los costos totales

No existe 1a menor duda de que sino existe expectativa alguna
4e que hayan los precios del petréleo (y 1as eupresas quieren mini-
saizar sus costos) 1a alternativa ser el cambio tecnológico y esto
fen términos del recurso de energfa implica el buscar fuentes alternas

de este recurso.

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

los sectores industriales de Puerto Rico necesitan del insuno
de"energia (combustible y electricidad) para Ievar a cabo su produc
cin. También el consumidor final denanda productos devivados del
petr6leo. En otras palabras que la industria de productos de petr6~
eo vende su producto a otras industrias para ser wsado como insumo

intermedio, y a los consunidores Finale:

De igual forma 1o hace el

sector industrial productor de electricida

La Tabla T dlustea 1a

denanda que hacen los diversos sectores industriales y el consumidor

final de productos de petrSieo en base al cusdro de relaciones

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interindustriales de 1972 publicado por 1a Junta de Planificaciéa.

Ls Tabla 2 muestra el porciento del total de costos que representa

1 gasto en productos (suninistrado por 1a industria del petréleo)

para los 25 sectores mis intensivos en energia (en este caso conbus~

eibles). Nétese que 1s propia industria de petréleo, 1a electricidad,

inerfa, construcci6n y cemento son las industrias més intensivas en

fel uso del combustible, por lo tanto las més afectadas en caso de

?aumento en los precios del petréleo.

EL cuadro nos indica que los costos totales de produccién (uso

de insunoe internedios

is el pago @ los factores primarios de pro-
duceiGn - capital, mano de obra, etc.) para 1a economfa de Puerto Rico fueron de alrededor de $12,071.1 milléa, de los cuales $491.9 millones fueron gastados por las industrias en consuno internedio de pro Guctos de petréleo. £1 consunidor final gast6 $70.8 miliones en productos derivados del petréleo. La cantidad denandada por los sectores industriales constituy6 el 4.1 por ciento de los costos totales (insunos intermedios ms valor aiadido) y el 8.8 por cfento del total de gastos en insuso in¢ernedios.

EL poreiento que constituye el gasto en insunos energéticos del total de gastos es una medida de céno se afecta 1a capacidad produc tiva de 1a econonfa total, © de los sectores industriales, en respuesta

a aumentos en los precios del petréleo. De acuerdo a un estudio re-

ciente para 12 economfa de los Estados Unidos y otras éconofifa

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mundials

The percentage response of capacity output to

one percent

?change in the price of energy is just equal to the share of

energy costs in total factor costs" (2)

Segin los estudios citados 1a economia de los Estados Unidos perdis cerca de un Sz de su capacidad productive debido # los aunentos en los precios del petrSleo. Asumiendo que 1a produccién total de Puerto Rico (igual al costo total) de 1972 se acereé al punto de né-xia capacidad y asumiendo que el "share" de energia a costo total (conbustible nis electricidad - 4.1 por ciento combustible y 1.0 por ciento electricidad) es del 5 por eiento (segin datos del cuadro de

insuso-producto de 1972) podemos estimar en forma aproximada 1a pér-
ida en capacidad productiva de 1a econoafa de Puerto Rico. Segin
nuestros efleulos nuestra economia perdié capacidad productiva en
alrededor de $603.5 millones. Aplicando 1a relacién de empleo a
produceién para toda 1a economfa (61.1 hombres por millén de dSlares
de produccién) podenos obtener una idea de 1a pérdida de enpleos.

Esta fue de alrededor de 36,846 empleos. Nuestros cSlculos estén

muy cerca de 1a cifra histérica de cambio en empleo de 1974 a 1975.
Segin 1a Junta de Planificaci6n el empleo bajo de 775,000 en 1974
(aio en que se aunentan los precios del petr6leo) a 738,000 en 1975

(una disminuciGn de 37,000 empleos)

(2) Véase: J. M, Griffin y P.R. Gregory, ?An Intercountry Translog
Model of Energy Substitution Responses,? Ameri
(Decenber 1976). Tanbitém R. H. Rasche y John A.

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Siguiendo los cBlculos antes eitados el 15 por eiento de aumentos
fen los precios del petréleo reducirfa 1a produceién del aio 1977(3)
($12,282.2 millones) en $92.12 millones 1o que implicarfa una pérdida
de 5,543 enpleos. Los datos antes seflalados nos dan une idea de 1a

magnitud del problema que tenemos por delante. :

Si los precios del petréleo no dissinuyen en el futuro insediato
Ja alternative serd buscar nuevas fuentes de energfa que reduzcan los
costes de produceiéa de los distintos sectores industriales y del con
sumidor final. Como explicamos antes 1a reduceién en costes aunentarsa
ruestra capacidad productiva y por ende el expleo de recursos hunanos.
Por ejemplo una reduccién en precio del recurso energético que dismi-

nuya los costos de produccién atribuibles

1 consumo de petréleo y
sus derivados en solo un 30% significarfa en términos noneterios unos
$150.0 mitiones en forma directa para toda 1a economia. La industria

de 1a construceién reducir:

sus costos en $44.2 millones, Ja manufac

tura en 954.7 millones y 1o que es ain ns importante ?1 costo de prom

ducir energia eléctricn se reducirfa en afs de §15 millones. No solo

se reducirfan los costos sino gue a capacidad productiva de 1a eco

nomfa aunentarSa en cerca de un 5 por ciento de 1a redvecién en precios.

Si la reduceién en costos inplica una reducci6n en las inportaciones

de 1a misma magnitud 1 producto bruto de 1a isla aumentarta ya que

habria um ineremento favorable en el saldo de nuestra econosfa con el

exterior (aumentarfa a nuestro favor 1a diferencia entre exportaciones

@ ure

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? importaciones). En otras palabras no solo habria aumento en 1a capacidad productiva y el espleo sino que habria substitueiGa de importaciones ayudando asf a nuestra balanza comercial. Solanente asumiendo que nuestra produceién bruta total aumentara (sobre los niveles de 1978) en un 2 por ciento se generarfan mis de 20,000 empleos adicionales. Sin enbargo con toda probabilidad el aumento en capacided pro~ ductiva debido @ una baja en los costos energéticos incrementarfa ?nuestra producci6n en un porcentaje mucho mayor. Por el lado de 1a

denanda 12 éisminveién en 1a tasa de inflacin incresentarfa la de~

manda final por bie

y servicios 'y el ingreso real disponible de

las familias. EL aumento en la capacidad productiva, disminucién en

importaciones, aunento en ingr

10 personal y aunentos en 1a demands

Final no hay 1a menor duda incrementarfa los ingresos al erario ptblico

fen una cantidad considerable, Solamente un ausento en 1a demanda

©)

Final (donéstica ?) de St increnentarfa 1s produceién de §15006.4

millones a $15,710.9 millones (sobre los niveles de 1978), 1 empleo

fen unos 36,000 y os ingresos netos al fondo general del gobierno

?en unos $74.0 millones. Sie} descubrimiento de una nueva fuente

?energética reduce los costos y sueenta 1a desanda final en un 9 por

ciento 1a produceiGn aumentarfa de $15,006.4 millones a $16,329.2

millones (a precios de 1972) 1o cual increnentarfa el empleo en unos

69,000 y e1 ingreso al erario pblico en aproximadanente unos $133.3

?millones.

?UY Genanda final donfstica no Tncluye Inportaciones. EI eGapato?

se hizo resolviendo e1 wodelo de inswao-producto cuya ecuscia es

X= Ci-A)?IF donde X-produceién, (I-A)-! matriz iaversa de Lentref y

Fodenanda final doaéstica.

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Estas cifras aproxinadas le ofrecen una ides aproximada al sefior

Legislador de 1a importancia que tiene el asignar algunos fondos para

?Research & Development? en el campo energético que redunden en el

descubrimiento de nuevas fuentes energéticas que sbaraten los costos

de produccién y los precios de 10s bienes y servicio:

-7e

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