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PHASE I REPORT

BIOMASS CONMERCIALIZATION AT CAMBALACHE

Prepared for the

MUNICIPALITY OF ARECIBO

and the

PUERTO RICO OFFICE OF ENERGY

by the

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

August 1985

---Page Break---

TABLE OF CONTENTS

2

2

3

4

centrifuging

+3 One Strike versus Three strikes

6 Mill operations

7 Improvenent and Repairs

8 Mill Operating and Maintenance Expenses

9 Value of the Cambalache Mill

---Page Break---

5.10 Sens:

THE POWER PLANT

---Page Break---

EXECUTIVE SUMMARY

Several major problems are hurting the economy of Puerto

Rico: the sugar industry is currently losing from §20 to $40

million dollars each year; the rum distilleries must import molasses to meet their needs; oil must be imported to produce

Just about ali of the energy consumed on the island; and une!

ployment has leveled off at an unacceptably high percentage of the available vork force.

With these problems in mind, the municipality of Arecibo, the Puerto Rico office of Energy, and the Center for Energy and Environment Research (CEER) of the University of Puerto Rico have Joined together to study the feasibility of reopening the camba~ lache mill. The mill, which is located near Arecibo and which served an area of 300 square miles, was closed after the 1961 cane harvest for financial considerations.

The project under study proposes to create the full-tine equivalent of 1,200 direct and indirect jobs by using 12,700 acres planted with new varities of energy cane and energy grass. ?These varieties have been developed at CER by a group of agri- cultural scientists who vere more concerned with total tonnage of ary matter rather than with sucrose content. Several successful experiments have yielded up to 128 tons per acre of biomass and have denonstrated that biomass is a feasible alternative enersy source.

The project includes the reopening of the Cambalache mill

and the construction of a new power plant next to it to provide

energy for the mill and for export to the Puerto Rico Electric

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Power Authority, The project will use equipment, technologies and crop management systens which have been commercially proven in Puerto Rico and Hawaii. This is not a project which depends on new technologies, but rather on a new combination of existing technologies. For this reason, the implementation of the project is primarily a management problem, not a technological problen.

?This report is the final report for Phase I of the project.

It covers the agricultural needs by describing the new varietie:

and projecting tonnage yields; it lists repairs and improvenents that will have to be made to the mill and describes the process that will be used to produce sugar, molasses, and bagasse. The new power plant has two alternatives and both are described at

length in the chapter on the power plant. Finally, a detailed economic analysis gives the background needed for an understanding of the electric power situation on the island and presents scenarios in which the Cambalache project will be economically feasible.

Concerning the area of agriculture, the sugar cane crop must be replaced by new types of energy cane and grass that can be harvested on a year-round basis. area farmers must be taught, Probably through the extension services program, about new methods of preparing the land, planting, cultivating, harvesting and rotating crop dwindled from 15,400

?The available land hi

acres in 1972 to 9,200 acres in 1980, and sugar cane has been replaced by dairy farming, pineapple growing, and an experimental rice project as the principal crop in the area. other problems include the uneven rainfall pattern which varies significantly

ii

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from town to town, poor drainage, and the need for irrigation of large tracts.

However, the yield of energy cane that can be produced by using variety US 67-22-2 with proper irrigation and drainage should average 85 tons of whole cane per acre per year over @ thr

?year cycle of one plant crop and two ratoons. The yield from variety PR 980 should average 66 tons per acre per year for the same cycle, and this is the goal for the start of operations. Yields of energy grass should average 59 tons over a period of three years, and these should improve as the grovers becone nore familiar with the energy managerent eystens. The total land Fequirenents for the Project are about 13,920 planted acres, or 25,310 ace in farm land allowing 10 percent for infield roads,

@rainage ditches, and structures.

Sufficient amounts of energy cane and grass can be grown in the Project area if proper attention is given to such problens as retraining, drainage, irrigation, and the need for changed work Schedules. A top priority for Phase IT of this study must be the verification of the availability of land in the Project area and the impact of its location on the length of the harvest season.

Regarding cane mill operations, the cane will be processed to give bagasse which will be used as fuel during the milling Season, and cane juice. This juice will be reduced to sucrose, which will be refined to pure sugar, and molasses, which will be used for the distillation of rum.

Since no maintenance has been performed on the Canbalache

mill since 1981, $1.9 million must be spent on one-time inprove-

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ments and repairs before the mill can be used, and $1.5 million in normal naintenance expenditures should be made during the first year. The Project assumes a target rate with traditional cane of 4,200 tons per day anda mill utilization rate of 90 Percent. Since the nill will operate with cleaner cane, better maintenance and supervision, and less dovn-tine than in the past, the mill is capable of processing 4,500 tons of clean cane or 3,900 tons of whole cane per day. Although the Sugar Corporation has valued the mill at $5.9 million, its actual value is more ike §3.6 million. This Project presents the opportunity to use the mill for a good purpose rather than to dispose of it for the used equipment or on the scrap market.

Concerning the new power plant to be constructed adjacent to the mill and near PREPA's 38 kv transmission line, the plant will use @ high-pressure boiler to convert such fuels as bagasse, Grass, and cane trash into steam. This steam will be fed to a turbogenerator for the generation of electricity for PREPA and the mill. During the cane milling season, intermediate and low-pressure stean will be extracted fron the turbine and sent to the mill for use in the milling of cane, the evaporation of water, the crystalization of sugar, and other purposes. the boiler will be capable of producing 215,000 pounds per hour of steam at 850 pounds per square inch with a calorific value of 1,494 BTU per pound of steam. The turbogenerator is of the double-extracting/condensing type with a planned output of 22,000 xu per hour when extracting for the mill. with 62 short tons of

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bage

¥@ and 9 short tons of fallen trash available per hour, the

boiler can produce 284,000 pounds of steam per hour.

Two alternatives should be studied further in the next

Phase. One alternative can provide 29,200 kw and the other 30,500

kw; the difference in initial cost is $3.8 million. Also, a

detailed operating plan covering each two weeke of the milling

ason should be prepared in the next pha:

?The report aiso contains a detailed economic analysis. The

analysis deals with the key question: will the various sectors of the Puerto Rican economy start to grow again fast enough so that PREPA must add new base-load electric-generating capacity within ten years. The analysis states that:

i. Without the benefit of inflation or subsidies, the project generates a positive cash flow from its fourth year of operation.

2. Net cash outlays total 36.4 million during the first five years, but the Project recovers this outlay and earns a

return equal to 12.2 percent on today's market.

By its sixth year, the Project will generate the equivalent of 563 direct full time jobs and 634 indirect jobs for a total employment of 1,197.

The entire Project must be undertaken by a single organization which finances the entire operation from its own resources at its own risk.

The report notes that PREPA will be straining ite debt service capacity if its moves to build a new coal power plant and

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that the authority will have to add a new bat

1993-94.

?load capacity for

?The demand and prices factors

also discussed in detail.

Conclusions and Reconmendat ior

?The design presented in Phase I of the study appears to be

feasible in all important respects, provided three conditions are mot:

© The basic sectors of the econony of Puerto Rico will grow fast enough so as to require a new electric generating capacity within the next ten years.

© Sufficient land will be made available for the project from land previously committed to the Rice Project.

The project will receive 100 percent tax exemption.

If there is a reasonable chance that these conditions can be met, Phases II and III of the study should be undertaken inmediately for the following reasons

©The project can contribute substantially to reducing unemployment in the Arecibo art

while making an acceptable

return on the investent.

© There are obvious ways in which the project design can be improved, for example, careful scheduling of planting, harvesting and transport; use of supplemental fuels during the milling

son.

© With or without modification, the traditional cane industry in Puerto Rico is no longer viable.

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* Creation of a new cane industry in Puerto Rico is a major option for agricultural development and petroleum inport Substitution which cannot be ignored.

e Any island-wide study of this industry must include Cambalache as one of the possible locations for cane nil-Ling, whether or not it is finally selected.

Ina complex study such as this, it is critical to maintain the momentum and cohesion of the project team.

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1.0 INrRoDucTION

1-2 Background

Sugar cane is no longer a profitable crop. sugar producers are faced with rising operating costs, both in the field and factory, overcapacity and excess stocks of sugar, declining demands for sugar, and lower world prices. This is a world-wide crisis with a great impact in Puerto Rico. Here the sugar industry has declined from the number one agricultural and industrial enterprise that once gave enployment to the major part of the

agricultural labor force to a mere shadow of itself.

While the Puerto Rico sugar industry declined in the past 30 years, the Puerto Rico rum industry has increased production and

has become an unqualified economic succe:

The taxi

from run

saul

are an important source of revenue for the Puerto Rican

government. The rum industry, however, is threatened by a lack of

sufficient domestic mola:

8, the basic feedstocks for run

Production, from the local cugar industry. Foreign suppliers now

Provide about 90 percent of the molasses used in the rum indus-

try. Dependence on imported molasses 1

as the rum industry

vulnerable to legislative action specifying a domestic origin of

nolas:

for rum bearing a Puerto Rico label, and to embargos and

shortages created by foreign suppliers.

Puerto Rico must import oil to supply 99 percent of its

energy needs, Oil prices have made dramatic increases in the past

decade forcing an economic burden on oil importers. Despite a

small respite in rising oil pric

because of energy conservation

and oil substitutes, future trends indicate that oil prices will

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rise as world o{1 consumption increase. This economic burden of

importing oi1 for production of electrical power has placed a

jevere restriction on the Puerto Rican economy.

In the meantime, even with slow economic growth and conti-

hued efforts at energy conservation and o{1 substitution, world

consumption of petroleum will increase at an average annual rate

of at least one percent over the next twenty years.

This plus declining production fron existing wells will

require the discovery and development of new oil wells with a

capacity equivalent to double the production from Saudi Arabia.

The new oil fields will cost more to find and develop than

existing ones, even if the organization of Petroleum Exporting

Countries dissolves and peace reigns in the Middle East. one

reason is that over half of the new oil will have to be found in

inhospitable areas such as in deep off-shore waters and in the

Arctic region. As a matter of fact, there is a strong probability that the politics of the Middle East will continue to be both

unstable and unpredictable. Thus at some point within the next
ten years oi1 prices will begin to incre

indefinitely at a faster rate time than other prices. In brief,

again and grow

cil prices will go up in less than it takes to install a large
electric generating plant, and the increase will be painful for
those who continue to depend on imports.

?Thus, the econoay of Puerto Rico is faced with a declining
sugar industry which produces about two-thirds of its sugar needs
at a loss of $20 to $40 million per year, insufficient donestic

Production of molasses for its viable rum industry, importation

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Of oil for almost all of its energy needs, and 22 percent unen-
ployment. The problems are basically lack of domestic fuel for electrical production, lack of domestic production of molasses for the rum industry, lack of an economically viable sugar industry, and unemploynent.

lon

cambalache Mill

The Central Cambalache mill is located a few miles from Arecibo on the north central coast of Puerto Rico. Tt ground Sugar cane grown in the municipalities of Isabela, Quebradilias, Camuy, Hatillo, Arecibo, Barceloneta, Manati, Vega Baja, Vega Alta, Dorado, and Toa Baja; a rectangular area 60 miles long by five miles wide or 300 square miles, The mill is located approxi-

mately in the middle of this are:

The area is a nearly level to sloping coastal plain and includ

the alluvial flood plains along the Arecibo, Manati and camuy rivers. Formerly, the main agricultural enterprise was sugar cane farming with some pineapple and dairy farming. since the mill closed in 1961, the main agricultural activities are @airy, rice and pineapple farming.

In the 1950's sugar cane was at the height of its reign in Puerto Rico, and the Cambalache mill vas seventh largest of the 33 mille operating in that period. sugar production declined in the 1960's and by 1969 the number of mills had decreased to 17 with Cambalache being sixth in the amount of cane ground. The decline of sugar production of the 1960's continued without in-terruption through the 1970's. Cambalache vas last in the tonnage ef cane ground of the seven mille still grinding in 19e1, the

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year that it ground its last harvest. From a high of 39,273 tons of sugar produced in 1952-53, Central cambalache produced only 11,080 tons in 1981.

Faced not only with a lack of cane but also with low sugar content in the cane (5.9 percent), the mill closed because of economic losses. The mill remains closed today, not because it is an inefficient operation, but rather because sugar cane growing is no longer profitable for the cane farmers in the Canbalache

1.3 The Future of sugar cane in Puerto Rico

The closed Cambalache mill serves as an example of the future of the sugar industry in Puerto Rico if the industry devotes itself only to growing sugar cane for producing sugar, as it has in the past. The out-of-pocket cost of producing a pound of raw sugar in Puerto Rico is 32 cents, yet the U.S. domestic market price is 21 cents per pound, and the world market price is about three cents per pound. The traditional approach is no longer economic and probably never will be again. A whole new cane industry with fundamental changes in every component activity must be created if Puerto Rico is to produce all the sugar and

mola

At needs, reduce its oi1 imports, and make a profit.

Beginning in 1977, while the Puerto Rico sugar industry was struggling for survival, a group of agricultural scientists at the Center for Energy and Environment Research (CEER) of the University of Puerto Rico began to take a new look at the sugar cane plant. Lead by Dr. Alex G. Alexander, head of the Bionase

Division at CEER, the group studied sugar cane for its inherent

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potential to produce large quantities of dry matter (biomass).
Sugar cane had traditionally been bred and handled agrononically
to produce one product only: sugar. These scientists removed the
agronomic restrictions imposed by the sugar cane grovers, and

?they allowed the cane plant to realize its full growth potential.

In field experi

nts at the Lajas Substation of the Agricultural
Experiment Station of the university, average yields of green
biomass of 110 tons per acre per year including 83 tone of

millable cane per acre were obtained. Further experiments with potential biomass cane variety US 67-22-2 gave 128 tons of green matter per acre including 100 tons of millable cane. Aleo evaluated were tropical grasses such as Merker or Napier graes (Pensisetum purpurem) that can be used as supplementary boiler fuel when the mill is not grinding cane

In 1979, using the results obtained from the Lajai

experi-

ments, CEER began to urge the use of sugar cane as a biomass energy source by means of project proposal presentations to the Office of the Governor of Puerto Rico, at biomass seminars, in

pr

Representativ.

ntations to the Agriculture Commission of the House of

of Puerto Rico, through papers written for scientific publications, and in newspaper articles. on June 1,

1980, a Memorandum of Understanding was entered into between Mr.

Jos

B. de Castro, owner of farmland in Hatillo, and CEER with

both parties stating their interest in the development of Puerto

Rico's terrestrial plant forms as renewable energy sources,

including the propagation of sugar cane as ?energy cane" with the

emphasis on the production of fuels and molasses from energy

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One of the objectives of the project was to establish on the

north coast a small energy cane plantation of about 25 acres

yielding 90 tons of millable cane per acre plus 10 to 15 tons per

acre of trash (cane tops and leave

) in an 16-month gran cultura

crop. Interestingly, after only one year of growth, the energy

cane crop produced over 90 tons per acre of millable cane.

The future of the Puerto Rico sugar industry is bleak;

however, based on the work of the CEER Biomass Division since

1977, a new opportunity emerges for an energy cane industry vith

sugar cane grown for biomass to produce renewable energy in the

form of fiber for boiler fuel for electricity and fermentable

solids for alcohol and sugar.

1.4 Purpose of study

can sugar cane be grovn and processed economically in the

Cambalache area as a bios

s8 energy crop to provide fiber for a

boiler fuel for electrical production, molasses as a feedstock

for the rum industry, and sugar for donestic consumption?

?This report is the result of a proposal for a complete fei

pility study of a cane-based sugar-energy complex to be
created at Arecibo, Puerto Rico using as a nucleus the Cambalache

Cane Mill closed since 1981. The proposal, "Biomass Conmerciali-

zation at Cambalache," dated May 7, 1984 was submitted to the

Puerto Rico office of Energy (PROE) by the Municipality of
Arecibo (the Municipality) with the assistance of the Center for
Energy and Environment

arch (CEER) of the University of
Puerto Rico. Under the proposal, CEER has primary responsibility

for carrying out the study.

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on September 18, 1984, a contract between PROE, the Munici-

pality and CEER was signed for CEER to undertake Phase I of the

study at a cost of $124,000 to be financed by a grant of $99,700

from PROE, one of $20,000 from the Municipality, and a contribu-

tion in kind of $4,300 from CER. The primary tasks of Phase I

are to determine if the project has a chance of being feasible

and to make a preliminary assesement of the condition of the

mill, the used PREPA turbogenerators, the weather in the area and

the availability of critical inputs such as suitable land,

irrigation water and rainfall. This is the final report tor

Phase I. It is accompanied by ancther document entitled ?sup-

plenentary Documents," which contains supplementary material of

related importance to this report.

1.5. Description of the Project

The project under study addresses all of the problens

mentioned abov

- I propos

to create the full-time equivalent

Of 1,200 direct and indirect jobs by using 12,700 planted acres,

the Canbalache mill, and a new power plant to be built adjacent

to the mill to produce electricity, sugar and molasses from cane

and Napier gra

Although the inputs and outputs are familiar,

what is envisaged is a new industry based on biomass. This

industry has four main components: agricultural operations,

field-to-mill transportation, cane processing and the generation

of electricity, primarily for export to PREPA, as summarized in

the following table:

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Although the project will produce electricity, sugar and

nolasi

, Operating methods in each component will differ from

thos

in the traditional sugar induetry and electric utilities:

@ The basic objective of agricultural operations will be to

ximize bionass production per acre, not the sucrose percent of

cane by weight or some similar criterion.

© The cane harvest will continue as long as weather pernits.

* te "energy cane" and "energy grass" management systens

developed by CEER and the Agricultural Experiment Station will be

used in the field.

Cane trash will be collected as boiler fuel;

Planting, harvesting, and transportation will be

closely coordinated to take maximum advantage of the

Weather and minimize the waiting time of equipment and

venicles.

©The cane mill will be modified and operated to produce

bagasse with 48 percent moisture (instead of the traditional 50

percent), "A" sugar (first strike), and "A" molas

(sector

than blackstrap).

The cane mill vill receive its energy fron the pover

plant.

¢ The power plant will burn bagasse, cane trash, grass and

agricultural wastes such as rice husks and pineapple wastes in a

high pressure boiler operating at a pressure of 850 pounds per

square inch above atmospheric (psig) anda temperature of 900

degrees Fahrenheit.

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© Except for a scheduled maintenance period, the power plant will produce electric energy year around for the PREPA grid and the mill. Steam for the mill vill be extracted at 150 and 16 psig.

The project will u

equipment and technologies which have been commercially proven in Hawaii, Puerto Rico and elsewhere or,

in the case of the crop mana

nt systens, thoroughly studied in Puerto Rico. Even in the latter case, local farmers are faniliar with most of the equipment and individual operations. Hence, this is not a project which depends on new technologies but rather on @ new combination of existing technologies. For this reason, the implementation of the project is primarily a management problem, not a technological problea.

1.6 In

Audience

?Tis report is for the Municipality of Arecibo which wants

to know if it ie £1

ible to reopen the Cambalache mill for

biona:

commercialization. It is for the Puerto Rico Office of

Energy to show the feasibility of continuing the study for Phases

TE and III of the Cambalache Biomass Commercialization Project.

The report is for sugar cane grovers in the Arecibo area and

Puerto Rico in general to show then that sugar cane grown as an

energy crop will allow them once again to grow cane a profit-

able crop. This report is for the people of Puerto Rico for it

offers them a chance to reduce their ofl imports for electrical

production, to produce sufficient molasses for their rum industry

and sugar for donestic consumption, and to give enploynent to

those people who will become part of the energy-cane sugar.

ergy

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complex. Finally, this report is for those who doubt that sugar

cane can be grown

2 profitable biomass crop so that they can

see that the concept is feasibie.

1.7, Plan of Development

The report covers the agricultural, cane mill, power plant, and economic sections. Each section provides sufficient data to

describe the work needed, how to accomplish it, and the costs involved. The more detailed information that was used in genera-

ting this report is available in the "supl

ntary Documents" for the specialists who wish to determine the basis of the findings and conclusions.

Phase I of the proposal, which is given in this report, covered the ¢:

period from September 17, 1984, to January 14, 1985, for field work, factory inspection, obtaining equipment specifications and prices, and interviews. The period from January 15, 1985, to the present was used to obtain compatibility of findings and decisions for the various section to achieve the

objectives ef the project; to make economic analyses of the Proposals in the field, mill and power sections to complete the economic evaluation of Phase I; and finally to write the finished report.

The work program of Phase I covered the following:

Agriculture Section: Land evaluation, varieties and seed material, machinery and equipment, and energy grass production.

Cane Mill Section: Investigation and evaluation of machinery

and equipment.

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BIOMASS COMMERCIALIZATION

AT CAMBALACHE

ENERGY CANE ENERGY GRASS

FIELD FIELD

GROWING GROWING, CUTTING

CUTTING MHOLE CANE DRYING BALING

IRRIGATION | DRYING A BALING

wHove CANE

s 7

u CANE JUICE

6 a BAGASSE

A CLARIFICATION ?a

R EVAPORATION orass

M toweressure | [STORAGE

1 ?Steaw

t © BOILING HOUSE]

LO ESRANUE ATION? fconcensare

"a" SUGAR

?aT MOLASSES

To MILL

{_____________steam © POWER PLANT

STEAM GENERATOR

ELECTRICITY ©] steam TURBINE

ELECTRIC GENERATOR

waTER@

ELectricity To

PREP.A.

GRID

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Power Plant Section: Turbogenerator evaluation, boiler

evaluation and biomass supply.

Economic Section: Nature of product market, and analysis of

complex.

Recommendations: Construction and operation schedule.

Report writing and Printing

1.8 Organization of the study Team

?The study team was composed of various qualified members of

?the CEER-UPR staff and consultants. They are as follows:

Project Director

Juan A, Bonnet, Jr., Director, CEER-UPR

Project Deputy Director

Donald S. sasscer, A

latant Director for Energy, CEER-UPR

Coordinator

Salvador Lugo, office of Planning and Development, CEER-UPR

Manuel Balzac, Consulting Engineer

Agricultural section

George Samuels, Biomass Consultant

George Cc. Jackson, Biomass consultant

cane Mill Section

Mariano Romaguera, Engineer and Appra:

Power Section

Henry Ramos, Consulting Engineer

Econonic Section

Lewis Smith, special Project Economist

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2.0 AGRICULTURE

2.1 Introduction

Since Christopher Columbus brought the first seed to Puerto Rico in 1493, farmers have planted varieties of the plant genus Saccharum, commonly known as ?sugar cane." Throughout history it was the single most important economic product on the Island and

?the foundation of the economy from the 1920

through the 1950's.

Today, with the out-of-pocket cost of producing raw sugar in Puerto Rico over 32 cents per pound, the U.S. domestic market Price near 21 cents per pound. and the world market price about three cents per pound, this traditional approach is no longer economic and probably never wil: be again (1). If Puerto Rico is to produce its ovn sugar and polasses in order to reduce its Petroleum imports, it must create a whole new cane industry with fundamental change

This

An every component activity.

ction of the Phi

I report discus:

8 the agricul-

tural activities and resourc

required to support the Canbalache

cane mill and an adjoining power plent as one of several nuclei

of @ new cane industry which might be established in Puerto Rico.

?The principal innovations required in agricultural operations

© Change the length of the harvest season so that cane can

be harvested whenever weather conditions permit, regardless of

rendiment (sucrose percent cane, by weight).

a

---Page Break---

© Use storable biomass such as cane trash, energy grasse: and rice husks to supplement cane bagasse and assure a year-around supply of fuel for the power plant.

@ Maximize the yield of total dry biomass per acre by adopting ?energy cant

?The:

and

ergy grass" management techniques.

techniques were developed by the center for Energy and Environment Research and the Agricultural Experiment station from 1977 through 1982 in the course of a joint research project, "Production of Sugarcane and Tropical Grasses ae a Renewable Energy Source," funded by the U.S. Department of Energy. Among the achievenents of this project, a plant crop of 96 short tons er acre of whole green cane with PR 980 was obtained on 17 acres of the José B. de Castro farm in Hatillo (2, p. 56).

© Rationalize the planting and harvesting schedules and the transportation activities to take advantage of weather patterns and minimize the idle time of farm equipment and cane trucks.

2.2 General Information about the Area

?The land to be used for growing energy cane and grasses for Project CBCP covers a rectangular region, 60 miles long by five miles wide or 300 square miles, on the north central coast of Puerto Rico. The area includes the municipalities of Isabela, Quebradilias, Camuy, Hatillo, Arecibo, Barceloneta, Manati, Vega Baja

Vega Alta, Dorado and Toa Baja. Thie is approximately the

area which the Cambalache mill

vad in the past; it reached a

Peak of 15,400 harvested acres in 1972. The mill is approxinate-ly in the middle of thie are us

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The area is a nearly level to sloping coastal plain and

includes the alluvial flood plains along the Arecibo, Manati and

Camuy rivers. At present the main agricultural activities are

@airy farming and pineapple faring. Prior to 1982, cane was the

major cultivated crop but it has now been replaced by rice. The

climate is favorable for the growth of cane and grai

The

average annual maximum temperature is 86°F (August to September),

and the minimum is 68°F (February).

The average annual rainfall is 62 inches; Arecibo is the

lowest with 56 inches and Toa Baja the highest with 68 inch

?The months of May through December average more than four inches

of rainfall each month. There is a drier period from February to

April. Actual precipitation in a given month may not

tthe

needs of the cane plant. An analysis of the amount of rainfall

in relation to th

needs shows that, on the average, there are

@eficits for the nine months from January to September, and

in November. mh

rainfall deficits must be made up by

irrigation during six months of the year for good cane and grass growth. However, seasonal rainfall patterns vary by municipality. Close coordination of farm operations will be required to Permit a steady supply of cane to the mill.

?There are 29 soil types found in the Project a Te six

Leading soil types with approximate acreag

are: Bayanén clay

(9,900), Toa sitty clay loam (6,200), Coloso silty clay (5,900), Almirante clay (4,900), Espinosa clay (3,700), and Bajura clay (3,200).

1s

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The majority of the soils in the area are gently sloping clay soils ranging from sandy clays to clay with clays as the predominant texture. The leading soils, as to acreage, are deep soils with subsoil up to 60 inches deep. They are well drained except for the Coloso and Sajura soils which percolate sloviy and have poor water outlets. The Bajura and Coloso soils flood frequently, and the Toa soils flood occasionally. The soil reaction (pH) is very acid to acid for most of the soils, ranging from 3.6 to 6.3. Most of the soils will require liming for better production. organic matter content ranges from one to five percent in the topsoil.

2.2. Field operations tor Eneray cane

?The cane plant naturally produces a lot of biomass, but only a little sugar. Moreover, in the tropics, the cane plant will grow year around and should be encouraged to do so.

Nevertheless, to grow energy cane, the farmer must use all

of his agronomic skills to obtain maximum biomass tonnage. To obtain this high bior

8s production, the farmer will have to learn to prepare his soil properly to allow the plant to produce large, vigorous cane populations: to supply sufficient fertili-zer, especially nitrogen to nurture the cane to produce nigh tonnag rather than

to use varieties that favor high tonnag

Sucrose; to maintain irrigation to supplement rainfall so as to

allow for optimum cane growth; and to harvest without burning so

that cane tops and leaves are also available for boiler fuel.

2.3.1. Land Preparation for New Plantings

The first step in growing energy cane and energy grass is

---Page Break---

Proper land preparation. soil tilth to depths of 18 to 24 inches

permits the energy cane plant's roots to grow and seek water and

nutrients without any restrictions, provided that soil acidity,

fertilizer, and vater availability are controlled.

The tillage

quence for a plant crop includes a first

harrowing to plow under the stubble and roots of the previous

ratoon crop; liming, if needed, to correct soil acidity: deep

plowing to from 22 to 24 inches; a second harrowing; land smooth

ing to facilitate surface drainage; and efficient irrigation.

Some fields will require spot leveling to remove high spots or

to fill in low areas too large to handle by land smoothing.

Most of the land involved in the project is on alluvial

Plains where soil permeability and infiltration rates are noder-

ate to slow. Most of the field operations are mechanized,

including harvesting. Deep rooting is essential for high biomass

Production. All these factors require that drainage should not

bea limiting factor. Existing canals will require renovation

and new canals may be required. Flood gates and pumps will be

needed on certain farns close to the ocean.

A network of mole and infield drains must be established to

drain the root zone on slovly permeable soils such as the coloso silty clay. A mole drain is a drain made up to 36 inches deep

in the soil by pulling @ torpedo-shaped metal cylinder (4 inches

in ail

jeter) through the soil by means of a heavy tractor.

Final

edbed preparation is undertaken after the infield

drainage is installed. This requires subsoiling to a depth of 22

to 24 inches to eliminate any soil compaction and to aerate the

v7

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soil. An additional step is the use of a rotavator, a tractor-

@rawn piece of equipment that shatters the soils to reduce large

clods and give excellent tilth to the soil for root growth.

2.3.2. Planting

Before planting the seed, fertilizer is placed in the furrow below the seed to insure the availability of the phosphorus to the nearby cane roots. The presence of nitrogen and potassium, also available in the fertilizer formula, insures a good start for the young cane plant as its roots energe and grow.

Soil and plant analyses will determine the correct amount of fertilizer to apply. Probably 1,000 pounds of a 20-10-10 ferti-lizer per acre must be applied in the furrow.

The seed used vill cone from seed-cane nurseries to insure healthy, vigorous seed free of insects and disease. Seed will be planted at the rate of 3.5 tons to four tons per acre and will consist of the whole cane stalk minus the tops. The cane should be from five to eight months of age, vigorous, and not dried out. overlap-to-double seed placement should be used to insure an average of two Viable dormant buds per foot of row, covered with

no more than tue to thr

Anches of soil and irrigated as soon as possible after planting.

Energy cane varieties capable of high tonnage production and vigorous growth will be used. Initial experiments with energy cane successfully used the vigorous PR 980, the major cane variety in Puerto Rico, although this is not one of the varieties recommended for the traditional management system. Further

testing revealed that US 67-222, an introduced but as yet unused

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variety in Puerto Rico, has even greater potential as an energy cane variety (2).

Besides PR 980, the Agricultural Experiment station has developed varieties for sugarcane production that show the vigor and cane-bionass tonnage capabilities needed for energy cane. In sone field trials, PR 68-2002, PR 64-618, PR 67-245, and PR 67-1070 have proved to be as good as or better than PR 980 in tonnage performance.

2.3.3, Cultivation

Rainfall is not sufficient for growing cane throughout the year except from October to December, and so irrigation is Fequired for high cane tonnage. The first questions that arise concerning irrigation deal with the source, quantity, and quality of irrigation water available. Budgeting for irrigation is difficult because neither the water source nor the amount needed has been determined. A complete study must be made in Phase IZ of the Project. Annual average requirenents for the Project area are estimated at three acre feet.

High-tonnage production of energy cane or grass requires larger fertilizer amounts than are used for conventional sugar

cane and grass production, especially nitrogen. Fertilizer

Schedules and rates are presently based solely on a review of experimental results and rates formerly used in this area. Soil and plant analyses and crop logs will be used to evaluate ferti-

lizer needs in Phai

II of the Project. The fertilizer will be applied in more than one application to insure maximum growth

throughout the year. The first application for planting consists

19

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©f 1,000 pounds of 20-10-10 per acre below the seed. the second, of 15-0-10 formula at 700 pounds per acre at eight to twelve weeks, is applied into the soil by machine and then covered.

If necessary, herbicides will be used to control weeds to eliminate competition for light, moisture and nutrients. appli- cations are best made with tractor-drawn sprayers and, in areas where tractors cannot operate, with knapsack sprayers. in Practice energy cane often grows fast enough to eliminate weed competition on its ovn.

Insect control will be directed mainly at white grubs (the larva of Phylapnaga spp. and Diaprepes abbreviati causing root damage; yellow aphids (Diaprepa abbreviatus adults)

major pests

en cane folliage; cane stem borers and wireworms. Registered insecticides will be applied when necessary by tractor-nounted sprayers.

Replanting of cane or grass will be

de when necessary. A

three-year cycle of one plant crop and two ratoons is recommended

for this study.

2.3.4 Harvesting

?The non-burning of the cane is one of the essential elements

of the energy cane concept. ?The energy cane will be harvested

and milled "whole," i.e. with tops and leaves attached, in order

to obtain the maximum cane biomass for boiler fuel. The harvest-

ing of cane with high tonnage

(over 60 tons per acre) will

equire machines not normally used for low tonnage cane harvest.

?The basic cutter for this work will be a V-cutter or coneja; it will cut the cane and windrow it. Loaders needed to place the

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cut cane into the trucks will be the boom-type with large grabs

Large trucks, preferably 6 x § with 40 tons capacity, should be used for transporting the cane from the fields to the mill. The cane must be delivered to the mill as clean as possible (5,7).

2.3.5 The Ratoon crop

After the cane crop has been harvested, the trash that renains on the field (primarily dried fallen cane leaves) will be raked, baled, and moved to storage areas for use as a supplemental boiler fuel.

The ratoon crop requires as much attention as the plant crop. It is the crop that is the most profitable as it produces greater tonnage for the same inputs. Field operations should

begin

soon as the cane trash has been baled and removed from the field. The various operations include eubsoiling, replanting

(1£ needed), irrigating a

soon as possible, fertilizing at 1,000

Pounds of 20-10-10 per acre before irrigation and 700 pounds of 15-0-10 per acre at then to twelve weeks, controlling weeds, and harvesting. Except for planting, the operations for ratoon crops are sinilar to those for the plant crop.

2.4 Field operations tor Energy Grass

Another major element in the energy cane concept is the use of alternate tropical grass species (primarily Pennisetum purpu em commonly known as elephant, Merker or Napier grass) as

supplementary biomass sources. uring the period the mill is not

grinding energy cane and supplying bagasse for boiler fuel,

energy grass is used. the Merker variety of Napier grass used in this study will yield two crops every five or six months produ~

22

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cing about 59 tons of green material per year. Each crop will be

cut by machine, solar dried, raked, baled and transported to

storage to be used as a supplomental fuel for electric genera-

tion. The energy grass is ratooned five ti

s over a three year

cycle.

?The majority of the field operations are similar for both

energy cane and energy grass, with the exception of the harvest.

The energy grass is harvested by a tractor-drawn rotary scythe

Bower-conditioner. Besides cutting, it also shatters the stem,

insuring an even faster solar drying. After cutting, the grass

is windowed with a tractor-drawn disc-type rake which collects

and turns the grass in neat rows for a second turning in two or

three days. Baling is done several days after owing, depending

on the a

red final moisture content, by using a baling system

that maki

square bales of about 0.7 tons in weight.

Field operations for cane and grass are described in detail

in tables A-1 through A-5 at the end of this section.

2.5 Extension Service Program

The production of energy cane and energy grass is a new idea in agriculture for Puerto Rico. Despite the apparent similarity

of many operations to those used in conventional sugar cane and

grass production, the new systens differ substantially from the
old and must be understood and folloved correctly. The best way
to propare the farmer for this change is through an intensive
extension service program. First, this will mean the retraining
of extension agronomists to be energy cane and energy grass

Proficient. They will then proceed to instruct and train

---Page Break---

growers who will be required to participate in this extension

rvice progran.

2.6 Re e_and

?The amount of land required for the production of energy cane depends on the capacity of Cambalache mill, its down-tine, and the length of the milling season. Because cane must be ground within hours after harvest, the length of the milling

?son depends on the length of the harvest season. This, in turn, is greatly influenced by the weather, especially the rainfall pattern. An important assumption of this phase of the study is that the mill has the capacity to grind 3,600 short tons Per day of whole cane with an average fiber content of 18.6 Percent, and that downtine will be held to 10 percent, as dis- cussed in the following section. Another assumption is that supplementary fuels will not be regularly available during the milling season, so that milling capacity determines electric generating capacity. the latter plus grass yields determine grass acreage.

All of these land requirements are imposed on an area that

does not have a surplus of agricultural land at present, an area whose cane acreage dwindled from 15,400 acres in 1972 to 9,200 in 1980 (5). This area has seen increases in dairy farming

and cattle raising and the beginning of a large rice-growing

industry on lands formerly devoted to cane. Also, come agricul~

ture land has been taken for busin

, Rousing, industry, parks,

roads, and schools over the last several decades.

---Page Break---

?This section estimates the approximate land needs for energy

cane and energy gra

production and the amount of suitable land

that is available for the Cambalache Biomass Conmercialization

Project.

2.6.1 Production per Acre

?The energy cane and energy grass management systems produce high biomass tonnage per acre. Yet the maximum yield of 121 tons of whole cane per acre obtained at Hatillo (2, p. 122) is not a realistic average for all of the land in the area being consi-@ered for the Project. Much depends on controlling limiting factors such as drainage and irrigation, and on the ability of the farmers to learn the skills required for growing the new crops.

The yield of energy cane that can be produced by using irrigation and variety US 67-22-2 or its equivalent should average 85 tons of whole cane per acre per year over a three-year cycle of one plant crop and two ratcons. Production using PR 980 with limited irrigation and some drainage problens should average 66 tons per acre per year for a three crop cycle. This is the goal for the start-up of the Project. Yields for energy grass are assuned to average 59 tons over the three-year cycle (2, pp 76-79). These yields should improve as the growers become more familiar with the energy management systens.

2.6.2 Length of the Cane Harvest and Milling Seasons

The length of the harvest

son is mainly determined by the

pattern of rainfall. he original planning for the Project cited

an eight month maximum harvest season for energy cane as a possi-

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bility (6), rather than the normal five-to-six month period

typical of the sugarcane management systen. The former is

possible in areas of limited rainfall such as those found on the

south coast of Puerto Rico or in areas with rather well-defined

Wet and dry seasons. However, the Project area has more rain

than does the south coast but

so has @ poorly defined rainfall

pattern as well. The latter problen affects the harvesting

efficiency of both cane and grass.

Although certain field work can be done on a work day

receiving more than 0.10 inches of rain, this condition creates problems at harvest time on infield roads and in the use of cane

harvesting machinery, and can lead to large accumulations of soil on the cane delivered to the mill. Based on the limit of less than 0.10 inch of rain per day, rainfall records indicate that on the average throughout the region, only seven months - December through April, June and July--have more than 15 days suitable for theld work.

However, this rainfall pattern is not uniform. Dorado and Toa Baja have fever field-work days than other municipalities; Manati has nor

Hence, by planning and coordinating plantings and harvests, this difficulty can be minimized. However, a flexible vork week will be necessary to take advantage of weather breaks.

Based on the information now available, the length of the cane harvest season may have tobe reduced to six or seven months. For the purposes of this report, the season is assumed

to be 26 weeks of five field work days each or 130 days in total.

---Page Break---

This gives a milling season of 182 days or, with 10 percent downtime, 164 eftective days. At 3,600 tons per effective day, total production will be 590,400 tons of whole cane. At 85 tons Per acre, approximately 6,950 planted acres are required,

2.6.3 Land Requirenents for Energy Grass

Since baled grass can be stored for months without significant deterioration (2), the season for energy grass need not be

defined. However, enough gra:

and other biomass must be avail-

able to meet emergencies during the milling season and supply the ower plant in the grass season. These calculations are shown in Table P-4 in the chapter on the power plant. Including 10 Percent for seed, the totel land requirements for the Project are about 13,920 planted acres, or about 15,310 acres in farm land, allowing another 10 percent for infield roads, drainage ditches, and structures.

2.7 Availability of Suitable Land

Zand suitable for growing energy cane and energy grass was delineated using the Soil Survey maps of the area. In addition to the 16,300 formerly committed to the Rice Project, a total of 14,570 acres were found to be suitable for energy cane and grass production (Isabela, 1,400 acres; Quebradillas, 370; Arecibo, 1,500; Barceloneta, 2,30)

?Toa Baja, 3,000).

Manati, 3,000; Vega Baja, 3,000; and

?The identification of these 14,570 acres does not mean that

this acreage is necessarily available for energy cane or grass

Production. Sone of this land is now in housing, educational,

school, comercial, and recreational areas. The land is, for the

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most part, in farms now devoted to dairy farming and beef cate!
Production. The owners or lease holders of this land may

resist the change from their present agricultural enterprise tc

that of an unfamilar crop for energy production. At present
enough suitable land is not available for this Project unless
some of the rice land is nade available

?The Rice Project does have much suitable land for energy
eane and grass production. Further study ie needed to determine
the actual acreage of land in the Rice Project and the lands that
could be made available for energy cane and grass

One of the determining factors for both land suitability and availability is farm size. A profitable energy-crop field operation will require the use of farm machinery and level land ?The use of farms of less than 50 acres will probably not result in an economic operation for energy cane, but smaller acreages can be used for energy gra

2.8 Acreage Requirements for cane and Grass

Table A~6 at the end of this section shows the acreage

needed for energy cane and energy grass for harvest seasons of from five to eight months with good production (85 short tons and 59 short tons per acre per year respectively) and average production (66 tons and 47 tons). Total acreage required in fares

varies little by the length of the harvest season but is sub-

stantially influenced by yields. cane production per acre for the

"average" case is 22 percent 1

than that for the "good" case:

grass, 20 percent let

but total requirements for land in farms

is 27 percent higher. The acres in cane and grass respect iveiy

27

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vary markedly with the length of the season. For example, with high yields, planted cane acreage varies from 37 percent of the total for a five month season to 59 percent for an eight month Season. Given the fixed initial investment required to rehabili-tate and improve the cane mill and the high U.S. price of sugar, the cane harvest must be extended as long as possible. However, because of rainfall patterns, it will probably be necessary to Limit it to about six months per municipality.

Atop priority for Phase II of this study must be the verification of the availability of land in the Project area and the impact of its location on the length of the harvest season.

2.9 Production costs for cane and crass

Although it is difficult to estimate field production costs for an area where energy crops have not been grown before, good

approxi

tions are essential to calculate the economic feasibility of the Project. Depending on the cost of capital assumed, the @elivered costs of crops account for about 65 percent of the total economic cost of products sold in year six of the Project, the firet year of power plant operation.

Tables A-1 through A-S at the end of this section show

@etailed cost estimates for each operation, for cane and grass

respectively, by crop (plant and ratoon). To the extent possi-

ble, these are economic costs

that is, market prices or market

based costs are used and subsidies eliminated. In particular,

irrigation water has been estimated at $64 per acre foot or 20

cents per thousand gallons, at the edge of the field. These

estimates are based on actual experience (2) and assume that both

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equipment and land will be rented. Rental was assumed not only

to simplify calculations but also becau!

On an equivalent basis, farm land is cheaper to rent for

farm us

than to buy. The rental is unlikely to include a

premium for conversion to other, more valuable uses; whereas the purchase price is likely to do so.

@ Most farmers will probably want to rent most of the equipment they need or make service contracts vith equipment owners.

The AFDA schedule of rates is used as the basis for equip ment rentals for two reasons, despite the probability that these contain elements of subsiay.

© Since many rentals would be made by farmers to farzers and/or with used equipment, actual average rates to be charged under the Project would probably be lower than life-cycle cost

sstimates based on new equipment.

@ In the tam

allowed, another internally consistent alter-
native could not be developed.

The cycle of a plant crop and two ratoons is the same as

that used in CEER?s original research work. Although sone

farmers

'y favor more rateons, production of energy crops falls

off sharply as the number of ratoons increases, especially with

irrigated cane, so a

to outweigh cost savings. The three-year

cycle of one plant crop and two ratoons is essential to achieve

competitive costs with the varieties indicated.

The average annual cost of cane over the cycle for 85 tons

of whole cane per year amounts to $1,150 per acre or $13.51 per

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Short ton at the farm gate. Transportation costs fron farm to

BAll are estimated to average $2.00 per ton. ?Total delivered cost is $1,405 per acre or $16.51 per ton. The most costly operations are harvesting, at $298 or $2.50 per ton, and irrigation, at $264 or $3.11. The highest material cost ie for fertilizer at $177 or $2.09. costs for the plant crop per acre are $1,366, compared to $1,040 for the ratoon crop. Per ton, the Plant crop costs $16.08 compared to $12.23 for the ratoon. However, in practice, yields will be below average for the former and above for the latter, especially for the first ratoon (2). Hence, the year-to-year spread in per-ton costs will be somewhat

Greater than indicated abov

The above costs are greater than those shown for energy cane

and sugarcane in (2) and (7), for example. Aside from inflation,

the following factors appear to be responsible:

©The higher yields of energy cane require greater expenditures on inputs.

* Soil and weather conditions are less favorable on the north coast than on the south coast.

* Harvest and irrigation expenditures are much higher than in (2) and (7).

The

timated annual cost per acre for energy-grass produc-

tion, based on 59 tons per acre per year fron two crops, is $1,528 for the first year and $1,186 for each of the next two, at the farm gate. Per ton, thie is $25.90 and $20.20 respectively. The cycle average is $2,300 or $22.03. The plant crop of energy

grass costs $935 per acre or $31.70 per ton as compared to 9592

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or $20.10 for the ratoon crop. Highest costs are for irrigation and fertilizers. Harvesting costs at $62 per acre or $2.31 per ton, for mowing, raking and baling, are much lover than for energy cane

The section on the economics of the Project will present a more complete analysis of the financial aspects of energy cane and energy grass production,

2.10 Conclusions and Recommendations

The evidence obtained to date indicates that energy cane and energy grass can be grown in the area covered by the proposed Cambalache Biomass Commercialization Project. Limitations

imposed by the uneven rainfall distribution, soil, drainage, and

water availability in turn will limit production per acre of both

energy cane and grass. However, proper attention to drainage, irrigation, so{1 preparation, fertilizers and varieties will make possible average yields of up to 85 tons of whole energy cane and 59 tons of energy grass per acre per year to mect the require: ments for an energy-cane feedstock and those for energy grass as

@ boiler fuel when the mill is not grinding.

Studies of the soils and topography of the area show that about 14,000 acres of land are suitable for energy cane and grass in addition to lands formerly committed to the Rice Project.

Since this Project requir

at least 15,000 acres of farm land,

top priority must be given in Phas

IZ to determine the availability of land and the impact of farm lecacion on the

harvest season,

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In summary, the agronomic work to be performed in Phase II includes the following:

© Determine land availability as described above.

Prepare schedules for expansion of crop land to desired acreage.

* Prepare planting and harvesting schedules by municipality, and a schedule of crop deliveries to the cane mill for every two weeks of the harvest season.

?Determine the best methods to coordinate harvest, transporting and mill activities to overcome changing weather conditions, including the possible use of a low-cost cellular radio systen.

* Evaluate the use of additional grass varieties to Permit farmers to intercrop or to extend the grass cycle to four years without excessive loss of yield.

Study the possibility of an "insurance arrangement" with grass farmers whereby, in case of drought, they may harvest energy grass crops early for cattle feed.

© Determine drying tines and storage methods for grass varieties to provide optinun moisture contents for combustion alone and for combustion in mixtures with bagasse.

* Define harvest procedures in detail so as to minimize

pickup of extraneous matter and maximize bionass collection.

© Define drainage and irrigation system requirenents.

© Evaluate the possibility of row spacing wider than tive

feet to minimize machine damage to stool:

© Define fertilizer application techniques.

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In conclusion, there is enough suitable land for the Project

within an economic distance from the mill. However, not all of

it is likely be made available. the rainfall pattern is a

proble;

because of its overall deficiency and momentary excess,

but this can be surmounted by careful planning and control of field operations that will require changes in the traditional

work schedule:

The training of farmers by extension personnel is of great

importance to the success of the project. Farmers must learn how

to grow energy cane and energy grass as = new crop rather than

repeat traditional sugar operations.

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as

---Page Break---

CANE MILL

: SECTION

---Page Break---

3.0 THE CANE MILL

3.1 The Need for cane Milling

Most grasses can be cut or shattered, left in the field to

Gry and then baled for use. This is not so with cane even though

it is a tropical grass related to corn, Johneon grass, and

Sorghum, When mature, the typical cane stalk is stiff, fiberous,

from 0.75 to 1,5 inches in diameter (1), and forms random piles

with a bulk density of about 13 pounds per cubic foot (2,p. 12).

Ite principal constituent is water, as shown by the following

table

Table M-1

COMPOSITION OF CANE STALKS

Energy Cambalache (5)

cane? 1971-1980 medians

Moisture 68 under 74% 73-748

Fiber wv 16 ais

Soluble

solids under 14 10m io-a6

*Equals (wedian percent pol 157I-80)793¥, ?

To complicate matters further, the most valuable compounds, fiber

and sucrose, are intermixed, primarily in the stalk. For these

reason:

the components of the cane plant must be separated and

the excess water removed in a large, complicated and expensive

collection of machinery known as a

ane mill" or, more commonly

esa "sugar mill." For the same reasons, an understanding of

both traditional and energy cane processing is necessary for an

understanding of the Cambalache Project.

---Page Break---

3.2 2 ane Mid,

The existing cambalache cane will will be repaired and

improved in order to process whole energy cane as it is received

from farmers. The cane (including tops and attached leaves) vill

be cut, crushed, shredded, and then milled ina tandem of 18

rolls to provide two intermediate products. The first is bagasse,

composed primarily of cellulosic fiber (45 percent) and extra-

cellular moisture (48 percent). The second is cane juice, a

Solution of water, sucrose and other mostly fermentable solids.

The bagasse will be carried in conveyors to the boller of

the power plant to be used as fuel during the milling season. In

view of the expected market conditions and energy costs, the cane

Juice will be purified, most of ite water evaporated, about 60

Percent of its sucrose extracted as "A" sugar, and the remaining

viscous liquid watered to an "A molasses", This molasses is

intermediate in sweetness between "high-test" (miel rica) and the

?plackstrap" (miel agotada or piel final). the sucrose, at 96

Percent purity, will be sold as raw sugar to sugar refinery.

?The molasses will be used for the distillation of rum. changes

in market conditions could, of course, lead to variations in the

Percentage of sucrose extracted from ¢!

juice, and hence, in the

end uses of the molasses.

9.3, The cane Milling Process

Cane stalks without tops or leaves are received at the mill,

weighed, unloaded and prepared by cutting and perhaps washing, and then shredded and crushed. At cambalache the cane arrives in

?Fucks and is unloaded Hilo-type unloaders. The cane then goes

---Page Break---

to a modern washing plant vhere it ie cleaned in a Cording-drum

Pressure water-vashing system. The juice is extracted by alter-

nately wetting the cane vith water and cane juice and then

Squeezing it between grooved steel rollers in a manner similar to

ills"

wringing a sponge. The rollers are grouped in sets or

(usually three per mill) and the mills (not to be confused with

the entire processing plant) laid out ina row called a "mill

sanden." The rollers are usually powered by steam turbines,

steam piston engines of the Corliss-type (as at Cembalache), or

electric motors. Prepared cane enters one end of the tandem,

pa

from mili to mill and cones out the other end in the form of bagasse. The cane juice is collected from underneath the tandem and is carried away for purification, evaporation and sucrose extraction.

Energy cane will be clearer than sugar cane because of the flat fields, closer field supervision, and different harvesting techniques. Since it will have tops and green leaves attached,

the tandem will have to operate at a slower rate. The moisture

content of the bagasse will be reduced from the traditional so Percent (3.5) to 48 percent, to meet the combustion requirements of the high pressure boiler in the power plant.

The principal stages in juice processing are

* Clarification (puritication with lime and heat) to renove impurits

* Evaporation of most of the water in the clarified juice,

ina series of vacuum-boiling vessels known as multiple effect

52

---Page Break---

"bodies" or "evaporators," to produce a syrup (m

jura) of about

65 percent soluble solids and 95 percent water.

© Crystallization of the sucrose in the syrup in a vacuun-

boiling vessel known as a ?vacuum pan" (tacho) to produce a den:

mass or "massecuite.?

© Centrifuging to extract the sugar crystals in the

cuite. The residual viscous liguid may be watered to "A" mola:

ses (as proposed in this study) or run through the last two

stages tvo or three more times to extract more sugar and produce

Weaker molasses (4). About 60 percent of the sucrose in the

cane juice is extracted in the first pass or "ay

sugar.

2.4 The Importance of Crystallization and

In these stages, the recovery of the sucrose in the syrup is

usually carried out by a cyclical process. These are critical

stops because their efficiency will determine the anount of

Sucrose recovered and the amount left in the molasses in each

strike,

?The usual process in modern ray sugar production is the

the

strixe system, The syrup is crystallized in the first

strike pan. Half of the strike is passed after crystallization to

the centrifuges while the other half is retained for the next

batch of syrup, ?The centrifuges produce raw sugar end molasses

and also sugary water from the application of water in the

Process. The first two products are called first or "A" sugar

and firs

oF "A" molasses. The other half of the strike is fed

with new syrup, first molasses, and washings.

---Page Break---

The first molasses then is moved to the second strike vacuum

Pan where ancther crystallization takes place with part of the output; the

cond or "B" molasses, is moved to a third vacuum pan. A similar process takes place for the third strike. The

residual liguid is watered to make blackstrap or final molass:

The centrifugation of the first strike is done innediately, whereas those of the second and third strike are deposited in tanks called crystallizers where a cooling of the massecuite is carried out by sets of revolving coils in the tanks.

?The final sugar (raw sugar which polarizes 96 percent or

more) is moved by conveyors:

the packing department where the end product is held in large bins for final packing. If there is a refinery, the raw sugar is melted for further purification to obtain sugar of 99.9 percent purity.

3-5 One Strike versus Three strikes

Traditionally, the efficiency of a cane mill has been

fured in part by the percent of the sucrose in cane which is
recovered from the centrifuges in the form of crystalline sugar.
Moreover, much of the energy used in juice processing would

otherwis

be wasted because it is low-pressure steam (At 12-16
Pound psig) from the exhausts of steam-powered mill equipment

and vacuun-

jel vapors fron multiple effect systems. Also,
most steam and vapors are condensed and returned to the boiler as
t

dwater. However, with the three strike system, energy require-

ents for juice proces

ing are large enough to require extraction

of & significant amount of steam from the turbine section of the

---Page Break---

turbogenerator

?ociated with the mill. This reduces the amount
of electricity available for sale,

By contrast, when only one strike is made, the juice proces
Sing operation is simplified significantly and less "new" heat is
used. Illustrative steam balances for the cambalache mill are
shown at the end of this section. Moreover, the optimum nunber

of strikes will be studied in detail in Phase II. Neverthe

experience shows that, when energy prices are expected to in-
orease and sugar prices to decline, one strike is probably
enough. This assumption is used in thie study.

3.6 Mill operations

Because of the time required to expand the acreage used for
energy crops and to switch from cane variety PR 980 to variety us.
67-22-2, the Cambalache mill should by repaired and improved is

Rediately, and it should begin processing energy and conventional
cane available wnile the power plant is under construction.
Thus the boilers and turbogenerators presently in the mill vould
be used during years one through five of the Project: no grass

would be w

a during thie period because it is uneconomical with
the old equipxent. Tabi,

M-3 through M-5 at the end of this

section show illustrative steam balances and other operating

conditions for the three situations already discussed:

Mea Typical, steam balance tor three-strike sugar ob-

tained by milling 4,200 tons per day of tradi-

f4onal 16 percent-fiber clean Cane, with exist=

ing boilers and turbogenerators.

Typical steam balance for one strike ("A") sugar,

obtained as in Table M-3.

---Page Break---

M5 ical steam balance for one-strike ("A") sugar

obtained from milling "3,600 tons per day Jof

Nhole 16.6 ?percent-fiber energy fane (fiber eguivalent of! above clean cane), with new (Power Plant.

In regard to these tables, note that from 1972 through 1978 Cambalache milled cane at an effective rate which varied from 4,416 tons per day in 1972 to 4,824 tons in 1975, with a median of 4,622 tons (3, p. 67). As a point of departure, the Project assumes a target rate with traditional cane of 4,200 tons or 91 Percent of the median. Since operating parameters are proportional to fiber content (6), the equivalent ancunt of vhole energy cane is 3,600 tons.

Under the Project, the mill will operate with cleaner cane, Petter maintenance and supervision and less downtine than in the Past. Also, juice processing will be considerably simplified by making only one strike. Therefore, the assumed rate of opera. tion for Phase I is conservative.

The target rate for mill utilization is 90 percent. This is high by historical standards for Puerto Rico (3, p. 69: 8, Appendix Table 9); but it is in accord with the best Dominican and Mawaiian practices. It is also important for the success of the Project. With new or rebuilt equipment, good management and good

maintenance

+ 90 percent utilization ie an attainable goal.

Mill steam requirements and energy available for sale under

the three conditions are compared in the following table:

---Page Break---

Table M-2

STEAM REQUIREMENTS AND ENERGY FOR EXPORT

eo

Ave. steam requirenents'

(ib per hour, by pressure)

150 psig	80,900	80,900	80, 900
16 psig gross	173,900	153,300	252,300
less exhaust	(27,700)	(771700)	(771700)
net	96,600	75,600	75,600

Ave. export ener:

(RW per hour)

735 29,8008#

* Mill equipment only. Excludes electricity generation and

turbine extraction

** See Power Section, Table P-3

Obviously, there is a significant incremental benefit fron

reducing atrik

?This may be seen by taking one strike as the

initial condition, If several strikes are added, sugar extrac~

?ion might be increased from 60 percent to 92 percent, or by 53

Percent. However, net requir:

nts for low pressure steam will

incre!

by 27 percent, and energy for sale will decrease by 100

percent.

However, by far the greatest benefit cones fron increasing

boiler pressure 5.3 tim

from 160 psig (to give 150 psig at the

tandem) to 850 psig. With no increase in the amount of cane or

fiber milled, energy for sale incre:

more than 25 fold. the

main reason for this is that the energy in s

mat thi

pres-

sures has three components: the energy required to heat water to

its boiling point (which inere

required to transform vai

with pressure), the energy

to steam (the energy of phase

57

---Page Break---

change), and the "super heat" or energy used to raise the steam above the boiling point. When a biomass fuel is burned in an efficient, high-pressure, high-temperature boiler (instead of the inefficient, low-pressure, incinerator-type boiler traditional in ?the sugar industry), the energy in the third component increases

disproportionately. Since this component supplies most of the

energy which moves the turbine rotor, electricity available for sale increases many fold. Although the cost of building and

operating the power plant increases, studies in other countries

have shown that the incre

ntal return on the investment required

to increase pressure and temperature varies between 20 percent

and 35 percent over a wide range of assumed costs. This matter

is discussed further in the Power Plant section of this report.

3.7 Impxovenents and Repairs

Qualified engineers have inspected the mill machinery,

equipment, and structure and determined that no maintenance

appears to have been performed on the mill since the end of the

last cane harvest in 1981. Moreover, the mill is bounded on the

west by the Rio Grande de Arecibo and few miles to the north by

the Altantic Ocean. As a result, some equipment such as the

Hilo-type unloade

have by

and structural members such as the roof,

n severely corroded.

However, with proper improvements, repairs, and maintenance, the mill is capable of processing 4,500 tons of clean cane per

ay oF 3,900 tons of whole cane. These matters are discussed in

Getail in the section "Potential Use of the Cambalache Mill for

---Page Break---

the Generation of Electricity," in the "Supporting Documents"

Section of this report.

The one-time improv.

ents and repairs estimated to be

required anount to $1.9 million and are summarized in Table M-6,

This matter must, of court

be studied in much greater detail

Guring Phase II. For example, the bearings of each tanden roll

should be exposed and their condition

uated. Nevertheless,

Table M-6 is sufficiently accurate for the purposes of Phase I.

Im addition, normal maintenance expenditures of about $1.5

million should be made the first year, even though little cane

may be ground.

3.8 Mill operating and Maintenance Expenses

Mili operating and maintenance expenses are detailed in

Sables M-7, "Estimated mill Payroll at capacity operation,? ues,

?summary of Payroll Expenses," and M-9, "Estimated Mill operating

and Maintenance Expense at capacity operation." separate esti-

mates of annual expen:

are shown for the first period (Project

Years one through five) and the second period (years six through

twenty-five). In the first period, it is assuned that the exist=

ing washing plant, boiler station and electric plant are in

operation. In the second period, the washing plant is shut down

and energy production transferred to the new pover plant.

Although these estimates are considerably lower than histo

Fical experience in Puerto Rico, the new cane industry can and should attain the:

targe

3-9 Value of the cambalache mi11

The Canbalache cane mili is valued in the books of the suger

59

---Page Break---

Corporation at approximately $5.9 million, of which the land

accounts for le

than $50,000 (7, p.55). However, the corpo-

ration or any renter would incur heavy losses if it attempted to

operate the mill in the traditional manner. Moreover, since there is no market for renting cane mills in Puerto Rico, the only meaningful values for the mill are those of the machinery and equipment for use elsewhere or of al1 renovable materials as

Scrap. In "Valuation of the Canbalache Mill" in the "suppienen-

tary Documents" of this Report, various methods of valuation of cane mills are discussed and a number of estimates calculated. This analysis concludes with the considered opinion of Mariano A.

Romaguera, Profes

ional Engineer,

follows:

fter careful consideration of all factors involved in the yaluation of machinery and equipment, fixtures and leasehold improvenents, it is our opinion that? the market value of. the Cambalache Cane Mill, not counting land, as of November 1984, Is gh the order of: $3,600,000 (three million six hundred thousand dollars) ."

This Project presents the opportunity to put the mill to a useful purpose rather than to dispose of it on the scrap market.

No value is assigned to the land because even if all the Femovable things of value were gold for ecrap, considerable

expense would be incurred to make the land usable for sone other

purpose.

3.10 Work to

Done in Phé

IT and rrr

Work during these phases will include the tasks such as

fe described in subsection 6 of the next section.

---Page Break---

TABLE Ha

TYPICAL STEAM BALANCE (SIMPLIFIED)

?THRES-STRIKE PROM TRADITIONAL CLEAN CANE

?CAMBALACHE MILL WITH EXISTING BOILERS AND TURBOGENERATORS

. T+ Composition of cane and bagasse

Clean Cane Bagas:

Short tons £ Short tens §

Water 3.108 75,9 137

Fiber 612 16.0 612

Soluble solids 4039.6 43

tant 2) os 2

Total per day 4,200 100.0 1874

er hour 175 618

M1. Heat contest of bagasse?

BTU per pound 48,099

Million BTU per short ton 8.199

per eay 12,085

er hour 503.5,

A, Sixemill tendem

(28 short tons of Fiver) x 110 by/ton

x 25 Ib/mp x 1054 Aw/mr 60,850

B, Blectriosty generation (for Mii1 use only)

(175 short tons of clean cane) x

42 kew/ton x 1358 x UO Ib/ew ato

c. subtotat Yo/mr 194,250

D. Rotler auxiiiaries

1. Forced graft blowers

Subtotal TT1.c, x 1.658 3,205

*won-cosbustible solids.

61

---Page Break---

Continued Table M-3 ~ Page 2

B

Soerioie

2, Boiler feed water systen and ener

live steam aysten

ney

Subtotal III.c. x 1.35% 2,622

Emergency makeup steam

Subtotal T11.c x 5.5% 10.683

Subtotal Ab/ne 210,760

Losses

1. Radiation

Subtotal II1.F x 10$ 21,076

2. Other

Subtotal IIZ.F x 54 a.538

Total requirement for steam at 150 psig

1. Average requirement Ab/ar 282,378

2 Operational flexibility desired

Average x 10% -2h2ar

3+ Peak requirement (rounded) Ib/nr 266,600

4, Boller capacity installed 354,000

5+ Excess capacity instelled under peak conditions (rounded)

354,000 1b/hr - 266,600 1b/nr St.400

Energy equivalent of average requirements

1. Energy in stes Bru/ib 1,227

Billion BTU/hr 297.4

2. Average boiler efficiency ? sen

3. Energy required in fuel million BTU/hr $71.9

4. Bnergy tn fuer

(61.4 short tons bagasse x 8.199 million BTY/ton) 503.8

creeasromiiiion BTU to be made up by burning a supplementary fue!,

8: 11 barreis of Ho. 6 (residual) oti fuel per hous.

62

---Page Break---

vate edarifier Ib/ar 13,230

Pre-evaporator 126,000

C. Vacuum pan makeup

184,900 Ab/ne = 126,000 b/ne 1.900

>, Subtotal Ab/ne 158,130,

E, Losses

Subtotai x 108 1g

F, Total requirenent for exhaust stoaa at 16 pate

1. Average requirement Bar 173,983,

2. Operational flexsbsiity desired

Average x 105 1398,

3. Peak requirenent (rounded) 191,300

A, Bxhaust available from prime eovers

under peak conditions

Subtotal IIT.F x 110% x 96% (rounded) 222,600

5. Bxcaas exhaust steam under peak conditions (rounded)

222,600 1b/nr ~ 191,300 1b/ar Y/mr 31,309

Y. Reguirenent for hot vapor at G28 psig sat

A. Secondary 1imed~uiced heaters Ib/or 18,480

Vacuum pans 59,640

Make up to secondary vapors from first body Btwrsy

(tirat evaporator)*

Total requirement for hot vapor

1. Average requirement, Berne 93,385,

2, Operational rexsbiiity desired

Average x 105 336

3. Poak requirement (rounded) Ab/me 102,700

?hsunes vapor from first body (first evapora:

in primary cane~Juico heater.

F) utilized for juice heating

63

---Page Break---

Continued Table H-3.- Page &

4+ Vapor avasiable from pre-evaporator under peak conditions (see IV 8)

126,000 Lb/hr x 1108 x 60% (rounded) 83,200

5+ Refielt of vapor available under peak

?conditions (rounded)®

83,200 byhr = 102,700 1b/ne £19,590)

?IT. Requirements for hot vapor at 4 peig sat,

A. Primary juice heater Ab/nr 4860

Total requirenent for hot vapor

1. Average requirement, Bo/ae 38,860

2 Operational flexsbiiity desired

Average x 10% kee

3. Peak requirement (rounded) iver 36,300

4. Vapors froa Cirst body under peak conditions

(roundee) 21,600

5. Ratioit in vapor available under peak conditions (rounded)

21,600 1b/nr = 38,300 ibvne Ame (16,700)

Sto be made up trom

reducing valve,

'xoess exhsust stean (IV.B.5) by means of pressure

---Page Break---

TABLE Hoa

. TIPICAL STEAM BALANCE (SIMPLIFIED)

ONE STRIKE (A) SUGAR FROM TRADITIONAL CLEAN CANE.

CAMBALACHE MILL WITH EXTSTING BOILERS AND TURBOGENERATORS:

1. Composition of cane and PA245¢°(se¢ Table M=1)

TH. Heat content of bagasse (see Table 4-3)

T1Y, Requirement for steam at 150 oaie, 415 dee F

?A. Sixemi}1 tandem (see Table H-3, T1I.A.) Lo/he 80,850

B. Blectricity generation?

1, Por mill use

(175 short tons of clean cane) x

12 kew/ton x 40 b/iew 84,000

2, For export (by difference)

~ 735 dow x 80 Ib/ew 29,400

c Subtotal e/a 198,250

D. Boiler auxiliaries and emergency eakeup

steam (see Table M-3, ITI. D and 8) 16.510

- 8, Subtotal a/or 210,760

Losses (see Table H-3, IIT, G) A618

G. Total requirement for steam at 150 paig

1, Average requirement 1o/ar 22,378

- 2. Operational flexibility (Average x 108) pagar

3. Peak requirement (rounded) a/nr 266,600

4, Boiler capacity installed 358,000

5+ Exauan capacity installed at peak (rounded) BL.400

TV, Requirement for exhaust steam at 16 oie aat

A, Jutoe clarifier (see Table M-3, IV. A) ab/or 13,320

B. Pre-evaporator (see Table H-3, IV. B) 126,000

. C. Vacuum pan wakeup ?

> Subtotal .b/ar 139,320

E. Losses (Subtotal x 10f) ta

; Tneduction 4s due to smaller loads on centrifugal, vater pumps and other

equipsent.

---Page Break---

Continued Table Het - Page 2

1

2, Operational flexibility desired (108)

3

4. Exhaust available from prine eovers

Total raquiresent for exhaust steams at 16

+ Average requiresent

Peak requirement (rounded) 1b/hr

under peak conditions

Suptotat 121.8 (this Table) x

M04 x 96 (rounded)

aig

Loyne

5. Exoaes exhaust unde peak conditions (rounded)

6.

222,600 iv/

= 168,600 1b/ae

Reduction in average requirements

We, Table M3, TV. Pt (rounded)

153,300 1b/ne = 173,900

A, Secondary Lined= juice heater

(se

Table #3, ¥, A.)

BLAM atetie vacuum pan?

©. Make up to secondary vapor from first body

(esest evaporator)

D, Total requirement for hot vapor at 6-8 paie

1. Average requirement

2. Operational flexibs}ity desired (104)

2

4

Peak requirenent (rounded)

+ Vapor available from the pre=

evaporator under peak conditions

(see Tabie 103, VD.

83,200 ib/nr = 65,600

+ Reduction in average raquirenents

vo, Table Me3, 7. D.1 (rounded)

59,600 1o/ne = 93,300

*aetualty two pans wi!

GID) be drawing hot spor.

Must be vented to atmosphare

66

aban

aber

abo

Lb/ne

aber

+ Eiagas of vapor under peak conditions (rounded)?

Loar

abn

153,252

15.325

168,600

222,600

54,000

11,600

26,775

59,600

65,600

83,200

11,600

be used, An off-set eycles, but only one at a tine

---Page Break---

TABLE M5,

TYPICAL STEAM BALANCE (SIMPLIFIED)

ONE-STRIKE (A) SUGAR PROM WHOLE ENERGY CANE

CAMBALACHE MILL PLUS NEW PONER PLANT.

1. Gonsoaition of cane, beeasse and trash

Wote cane Bagasse Fallen trash!

Short tons 1 Short tons $?Short tons £

ater 2,69 68,6 128.0 83 20.0

Fiber 670 18.6 6105.2 171 80.0

Soluble solids 432 12.0 3 28 =e

aan? 2 Oe 58 ag -

Total per day 3,600 100.0 1,483 100.0 214 100.0

er hour 150 62 9

TL, Heat content of basasee and trash?

BTU per 1b 4,266 6,672

Million BTU per short ton 8.532 13.30

per day 12,653, 2,856

er hour 527.2

Tr, Requivenent for steam at 150 nate, 415 des F

A. Sixemi1i tandes (see Table #3, 111, 4)" ab/ar 80,850

B. Total requirement ror stean at 150 psig?

1. Average requirements bye 80,850

2, Operational flexibility (10f) 08s

3. requires 28.990

"Non-conbuse ible ol te,

two thirds of Feld production,

{ish neating value per Havasian version of Hessey?s forma.

ne change in the asount of fiber per nour,

?We stean or electric: ty generation 1n Mill, All energy used by Mill is

obtained from Poner Plants

---Page Break---

Continued Table M-5 - Page 2

1V. Tela ceouirement for exhaust steam at 16 psig sat

1. Average requirement

(see Table Not, TV. F.1) Lbfmr 183,252

2. Operational Flexibility desired (10%) 15.325

3. Peak requiresent (rounded) 168,600

A. Exhaust stear available fron mili tanden

?under peak conditions

80,850 ib/nr x 110% x 96% (rounded) 85,400

5. Net requirenents for stean

a, Average (rounded)

153,300 1b/nr = 80,900 ab/he x 96% 75,600

>. At peak (rounded)

168,600 Lb/hr = £5,400 Lb/ne ib/er 83,200

(see Tabie 4-8, ¥)

ve

(see Table #23, VI)

6a

---Page Break---

TABLE HA

IMPROVEMENTS AND REPATRS TO MILL IN PROJECT YEAR ONE

jetubing of existing bottlers 3 180,000 540.0

2 Replacement of galvanized iron sheets on

Poof (square feet) 85,000 x 30%" = 25,500 9.00 230.0

3+ Repair carrier chains for cane and bagasse

conveyors ump oun 50.0

A. Repair heat-retaining insulation on

Piping and pressure vessels {about 20%

of total aurface area) usp sus A200

?Subtotal (Item 1-8) sko.0

New "Silver CoS" shredder with 1,000 hp

turbine drive (or heavy-duty electric

rotor) and substation

Equipment (delivered) 1 240,000

Installation, foundation and feed

conveyer luap sua

?Subtotal (shredeer)

6, Fuel handling and storage factitties!

Conveyers for bagasse and/or chopped

>

grass (lines! fer 240 300 12.0

?Storage busiding (60 x 120 x 2h) space

and return conveyer, usp sun zo

Subtotal (fuel facilities) ao

Te Weighing scare ? 6,000 86

8. A sugar contestuges 3 90,000 180

Subtotal (stone 1-6) 1798.0

9. Overnead and inepections

tens 1-8,7,8 108 121,000

Teese 5-6 * 29.000

Subtotal (overhead) 150.0

?Total (items 1-9) 1,988.0

[is addition to existing equipment. Does not include suehinery for bresking up bales

of ers

---Page Break---

?TABLE M-

ESTIMATED MILL PAYROLL AT CAPACITY OPERATION

ore

Wo. Description S7HOUE/peTSOn?$/Mo./peTeon Annual §

nC S7Rour person

Administrative personne!

1 chief engineer 2,330 28,000

a Asst. engineer 2,670 20,000

a Chief chemist 1/830 22/000

1 Asst. chenist 1/000 12/000

i Ereckyi0@2 engineer (instrument expert) 2/170 24/009

i Clerk 4:28 8,500

Subtotal 126,500

jason)?

Shitt personnel (milling

Laboratory

2 Laboratory analyst 800 18,200

i Sampler 3.95, 15,500

Subtotal 33,700

cane yara

2 Foreman 950° 18,300

i Gane analyst/core sampler 800 = 18,200

2 Asst. analyst 4.5 26,300

2 Payload operator 450 17,700

2 Crane operator 33,500

4 Utility: person 85,300

1 veility person dies 35,200

Subtotal 185,500

Washing plant?

1 Foreman 700 15,900

2 Console operator 3.95 31/100

Subtotal, 47,000

?e/yeari 40 hours/week. All receive lodging as well, except

ye ani fer /ROUFLY Personnel based on 164 effective opera-

Pisanenifts/aey; 8 hours/shitt and no overtine, (for beece

Hane see "summary" at the end of table).

*Project Years one through five only.

---Page Break---

Continued Table M-7 - Page 2

Milling tandem

a Foreman

1 Mill feeder

1 Operator

1 oiler

a Plate cleaner

Subtotal

Eilter, evaporation and vacuum fe

2 Vacuum pan operators

2 Vacuum pan asst

3 veility person

Subtotal

Centrifugals and weighing station

a

i

3 Utility" person/veigher

Subtotal

Boiler station?

a Foreman

1 Payloader operator

2 Boller feeders

2 Bagasse handlers

Subtotal

sper

utility person

subtotal

?narvest years one through five only

n

4.50

4:50

3195

3195

4.50

450

3195

5-00

425

425

3.95,

2,770

800

200

200

18,200

71700

171700

15/s0c

£500

24,600

125,800

31/100

48.600

202,500

18,200

35/500,

461600

-80,300

18,200

17,700,

35,400

18,200

19/700

16,700

16,700

---Page Break---

Continued Table M-7 - Page 3

Machine shop personnel?

Foreman 900

Lathe operator 5.00

Asst. 11

Carpente!

Helper 3195

Subtotal

na

10,800

20,000

18/000

17,000

471400

113,200

---Page Break---

TABLE M-8

SUMMARY OF PAYROLL EXPENSES

GETS aa ?

expense expense average

Project years 1-5?

Adninistrative 126, 500 116, 500

Laboratory, 200, 35/700

Cane yard 89,200 185,500

. Washing plant 31/509 47,000

Miling conden 84/600 34,600

Filter, ete. 94,000, 108,500 203,500,

Centritugals, ete. 33/709 46,609, 80/300

Boller station 83/200 33,200 102/400

Power plant 34/300 34/200,

Miscellaneous 34/800 32,000 86,800

- Machine shop 54109, 58,500. 113/209

subtotal 680,600 407,100 2,087,700

overtime? a. 85,800 85,800

- Subtotal 680, 600 492,900 2,373,500

Fringe benefits? 17; 0 0, 74

Tota 918, 200 665, 400 1,584,200

. $/short ton* 2.127 2.683

Profect_veare 6-255

Total 736,700 574,900 1,312, 600

$/short ton* 0.974 1.980

jiith existing boilers and turbegenerators.

Zequais total sniet payroil x 108.

{Equals Last sustotal x 35%. Includes vacations

: {Based on 164 ettactive days/year and 1,600 tons/day of whole cane.

foftects closing of Washing Plant and transfer of energy produc~

tion to Power Plant.

2

---Page Break---

TABLE M-9.

ESTIMATED MILL OPERATING AND MAINTENANCE

EXPENSE AT CAPACITY OPERATION

Sa

Expense expense Average

eS

Project years 1-5!

Payroll expense? 918,800 665,400 1,884,200

Other operating expens 248,100 179,600 427,700

Maintenance expense! 97.400 402,609 3,300, 000

Total 1,264,300 2,247,600 3,512,900

? 26.0 64.0 100.0

S/short ton? 3.807 5.948

Project years 6-25°

Payroll expense? 736,700 574,900 2,322, 600

Other operating expens 198,900 155,200 354,100

Maintenance expense? 73,000 052.000 25,000

Total 1,008,600 2,782,200 2,790,700

. 36.2 62.9 200.0

S/short ton? 3.018 4.727

jiith existing boilers and turbogenerators.

2prom Table M-5.

{Allocated in proportion to payroll expens:

[Allocated by aitterence. Total estimated independently.

gBased on 164 effective days/year and 3,600 tons/day.

fxettects closing of Washing Plant and transfer of stean and e:

tric generation to Power Plant.

Tannual average equals 75% of average for years 1-5.

oy

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4.0 THE POWER PLAN?

4.1 The Power Plant

A new power plant is to be constructed adjacent to the south side of the mill and near PREPA's 38 kilovolt (kv) transmission Line. This plant will receive fuels from the mill in the form of bagasse, from the supporting farns in the form of grass and cane trash, and from other sources such as rice husks from the rice

farms. Using a high-pr

sure boiler, the plant will convert these fuels into steam which will in turn be fed to a turbogener-

ator for the generation of electricity for PREPA and the mill.

After passing through all stages of the turbine rotor, the spent steam will be condensed to water and returned to the boiler for reheating and reuse. During the cane-milling season, interne~

diate and low-pre:

ure steam will be extracted from the turbine

and sent to the mill for u:

in the milling of cane, the evapo-

ration of water, the crystalization of sugar, and other purposes.

if it is not so used, much of the heat value of the extracted

m will otherwise be lost in condensation.

The power plant consists of three main units - a boiler

station, a turbogenerator (7G), and a switchyard - and a number

of common facilities such

the plant building. the boiler

station includes a boiler capable of producing 315,000 pounds

Per hour (1b/hr) of st

at a pressure of @50 pounds per

?Square inch above atmospheric pressure (psig), a temperature of

900 degrees Farhenheit (deg F), anda calorific value of 1,454

British thermal units per pound of steam (BTU/1b), when oper-

---Page Break---

ating at an overall efficiency of 64 percent. The TG is of the

double-extracting/condensing type with a planned output of 22,000

Kilowatts (kw) per hour when extracting for the mill. Its nominal

capacity is 29,200 kw when all spent stean is condensed. Elec

tricity is generated at 13.8 kv (three phase, 60 cycle) and

transformed in the switchyard to 38.0 and 4.16 kv respectively

for distribution to PREPA and to substations within the mill.

Additional technical parameters for power plant equiprent

are found in the "supplementary Documents" of this report. as

shown in Table P-2 at the end of this section, the total cost of

the plant is es

ted at $28.3 millon, excluding charges for the

use of funds invested. construction time -- including prepara-

tion of final designs, obtention of permits, erection of struc+

tures and the manufacture, delivery and installation of equip-

ment - is estimated at five years. Most of the expenditures will

occur in the fourth and fifth years.

4.2 Sizing of Equipment

When designing a new industry around an existing cane mill,

the design capacity and present condition of the mill, the avail

ability of land, the physical composition of the cane to be

Processed, and the cost of storing fuel, taken together, impose

Gefinite limits on the conceptual design of the power plant.

Furthermore, cane must be proc:

4 within hours of del?very to

avoid decomposition of the sucrose and physical deterioration of the plant stalks. Finally, to assure the reliability of electric

Generation, the baga

storage facility should be filled early

?

---Page Break---

im the milling season. Therefore, unless a supplemental fuel such as energy grass is continuously available, the capacity of the generating equipment will be determined by the peak cane-Getivery rate plus the requirenents for operating flexibility of the mill and the needs of the customers for electricity. in the fraditional sugar industry, cane deliveries are often quite Arregular and soxetines unpredictable. However, under the Project deliveries are expected to be fairly smooth because of the greatly improved coordination of planting, harvesting and transportation.

When supplemented fuels are continuously available during the milling season, there is much greater flexibility in both @esign and operations. the capacity of the generating equipment may Pe considerably greater than the maximum supported by bagasse stone, including bagasse withdravn from storage. th auch a case, the generating capacity is likely to depend on a comparison of

increnental

jarginal) costs: that is, whether it is better to

aad a little more capacity to the biomass power plant or to soe

conventional fossil fuel generating station elseyhere.

Mowever, the land requirements are still not known because

of the commitment to the Rice Project. Therefore, to minimize

tand requirements in Phase I of this study, supplemental fuele

vere

fumed to be available only for emergencies or during

pormal periods of mill maintenance. Furthermore, the harvest

schedule will be developed in Phe

II. For these reasons, the

capacities of the boiler and generator in Phase I have been

Getermined by the average expected deliveries of cane and fallen

8

---Page Break---

trash to the mill plus an operational flexibility factor of 10

Percent of capacity.

As shown in Table M-5 of the preceding section of this

Teport, the amount of fuel available to the power plant during

the milling season is, on the average, 62 short tons of bagasse

and 9 short tons of fallen cane trash per hour, with a maxinun

calorific (high heating) value of 646.2 million stv's. under the

boiler conditions described previously, this will produce 284,400

Pounds per hour of steam, Boiler capacity is thus set at 215,000

Pounds per hour, providing an operating margin equal to 10.8

Percent. The capacity and other parameters of the 76 follow from

this and from the extraction needs. The 7G capacity in turn

@etermines the level of operations during the non-milling season

and, consequently, the amount of land required for energy grass.

Nevertheless, in Phase II the effect of fluctuations in cane

deliveries on equipment size must be studied in detail, with and

without supplenental fuels. The tradeoff between larger equip

ment size and greater flexibility in field operations must also

be evaluated, particularly because the municipalities which would supply fuel to the mill have different rainfall patterns.

4.9 capacity splitting

Although most of the major equipment used in the mill and Plant are not "off the shelf," all of them have basic designs. 3f properly operated, their performance is reasonably predict~ able. Thus fairly precise calculations can be made about the advantages or disadvantages of dividing the capacity of a given

Piece of equipment between two or more units, for example, be-

---Page Break---

?tween tvo TC's instead of on

In most bionass energy projects,
the economics of dividing depends primarily on whether the crops can be left in the field or processed elsewhere and at what cost. With one exception, this matter is beyond the scope of Phase 1 and will be studied in Phase x1.

Because thr:

G's with @ nominal capacity of 20,000 kw each

are in storage at the san Juan steam Plant and one of 16,500 kw

at the former Rincon Nuclear Plant, the possible use of one of

Shese units in conjunction with a small new 7G was evaluated as

Pert of Phase I, As described in the "supplenentary Docunents"

of this report, detailed consideration was given to an alterna

five (Alternative B) comprising one used 76 of 20,000 Kw in

conjunction with a new, doubl:

xtracting/condensing unit of

20,500 kw. ?The total capacity of Alternative 8 when all spent

steam is condensed is 30,500 kw, as compared to Alternative A,

the alternative discussed in this section, with 29,200 kw.

Under the assumption that minimum supplenental fuels can be

obtained during the willing season, Alternative B will be

studied further in Phase II for the following reasons:

* The initial investment required for Alternative B in $32.1

mitlion, versus 28.3 million for Alternative a. this is

Primarily due to the need to expand or duplicate a great many facilities when there are two 16's instead of one.

© Te used 20,000 kw TG has small extractions suitable only for heating boiler feedwater (for example, 40,300 1b/hr at 20,000 Xu). Most steam for mill use must be passed through and extrac-fed from the new 7G. The high unit cost of a small, double-

---Page Break---

extracting/condensing T¢ takes avay part of the savings made by the purchase of = used To.

?Alternative B generates slightly more electricity for export than Alternative A, but most of this is during the Ron-milling season when the boiler is burning grass. conse~ quently, Alternative B loses money on the incremental until the Price of export electricity reaches about 10 cents per kilowatt hour because of the yields per acre assumed in Phase T.

© There is no security gain from having two 76's instead of ene. The used 76 of 20,000 kw cannot supply the mill by itself.

However, this matter will be studied further in Phase Ir.

With the possibility of having supplemental fuel ona regular basis, two G's (one used and one old) may prove attractive.

Without supplenental fuels, the used TG has an idle capacity of 6,650 kw during the milling season.

4.4 Equipment prices

The factory cost of the boiler and 16 were estimated from budget quotations requested from manufacturers during the course of this study, other items vere estinated in relation to these and/or on the basis of ratios extracted from historial estinates for power generation plants in Puerto Rico. Most of these other items were estimated on the basis of cost in dollars per kilowatt.

Budget quotations used for the boiler included the follow-

ing:

a1

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Babcock & Wilcox International

Sterling Power Boiler design (vt-40s)

290,000 Ib/nr

(f0.b. shop plus freight to port of export) $5,830,000

Combustion Engineerin

?Top-supported design (vU-40)

290,000 1b/nr

(e.4.f, san guan) $5,500,000

The scope of supply for the

quotations includes the boiler

itself; air heaters; controls and instrumentation; an economizer;

feed punps and drives; a force-dratt fan and motor drive; an

induced dratt fan and motor drive: a mechanical dust collector;

mountings and valves; platforms, stairs and walkways; refracto-

ries, insulation and lagging; soot bloers with control panel;

structural steel; a superheater; a travelling grate stoker with

Guctile iron links; spouts for bagasse feeding and export packing. The above quotations were scaled up to 315,000 1b/hr c.i.f.

San Juan, allowing for economies of scale.

Budget quotations (c.i.f. San Juan) used for the 16 included

the rollowing:

General Electric

19.6 mw (with or without extraction) $ 4,800,000

?BC _Brown Boveri,

20.0 mw (without main condenser) $ 3,800,000

The above quotations and cost estimates for related equipment

were scaled up using throttle-steam 1b/hr, condensate lb/hr or

yw as appropriate, The Brown Boveri estimate was also increased

---Page Break---

to reflect the fact that it was made when the exchange rate

between the German mark and the U.S, dollar wes about 3.0 to 1.0,

compared to rates which seldom exceeded 2.5 to 1.0 in th period

3973-83 (2).

A closed toop, circulating water system with cooling tower is mandatory for the T¢ condenser. The prime source of water for

this system is the nearby Rio Grande de Arecibo, which

subject
to flooding, high sedimentation, and turbidity. With the cooling tower in a closed loop with the condenser, only makeup water will be required to replace that lest through evaporating and the systens will not be effected by river floods. The need for a water treatnent plant will be studied in Phase IZ.

4.5 Operating Practice

The plant will be an area base-load electric generating Plant. That is, it will generate power for the PREPA grid on a reliable basis and at a steady rate with only minor, step-wise fluctuations, Tt will not ordinarily be used to meet peaks or as spinning reserve, The latter is normally impossible during the milling season, when extractions must be made for the mill: both options are usually uneconomical in any case. Also, the plant vill operate at pressure and temperature well above those for sugar milling, but in the lower part of the range traditional for electric generation.

At the same time, the plant must also aupply steam to the

mill at two different pressures for two different operations. The

mill tandem is a continuous operation subject to some fluctuation

---Page Break---

end to occasional interruptions, planned and unplanned. This operation uses stean of intermediate pressure (150 psig). Part of the low-pressure steam (16 psig) for cane-juice processing is obtained as exhaust from the mill prime movers and part directly

from the TG. Juice processing is primarily a batch operation.

The boiler pressure of 850 psig at 900 deg F has been Selected because of the foregoing circumstances. Economics alone would probably dictate a pressure of 1,250 psig, but this pressure inadvisable from the operations point of view.

Every one connected with the Cambalache project must be conscious of the foregoing and what it implies for operations. in particular, there must be a much greater degree of care, efficiency, and maintenance than was customary in the old sugar

industry. Sloppiness and carelessness cannot be tolerated

because they can be expensive and dangerous (2).

At the same tine, there must be a much greater degree of coordination during the milling season than utility personne! are accustomed to. When a problen develops, one cannot simply take a boiler and 16 pair "off the line? until someone figures out what the problex is and what to do about it. the mill cannot be left without steam while cane ie being milled or juice is

being processed,

Careful attention must be given to the recruitment, train-

ing, compensation, retention, supervision and periodic retraining of personnel. In a very real the creation of a new cane

industry in Puerto Rico 4s not an agronomic, financial or techno-

aa

---Page Break---

logical problem; it is primarily a managenent problem with

psychological implications.

However, the task is not as difficult as it seems. In the

first place, caribbean people in general and Puerto Rican people

in particular have shown an extraordinary ability to adapt to new

skills, new tasks and new ways of doing things. For example,

nore than 10,000 people learned to build refineries and petroch

sical plants; more than 8,000 to operate then. at the peak of

the industrial developnent program, sone 300 of the more than 450

?four digit" manufacturing industries were represented by at

teast one establishment in Puerto Rico. It would be strange if

People in agricuiture today proved incapable of mastering a

smaller and less difficult "technological leap" or turned out to

be slow learners. In the second place, Hawaii has over a decade

©f experience in operating cane-based cogeneration systens at

pre:

ures of 800 to 1,250 psig, in seven different mills. The

technology exists, and it can be used in Puerto Rico.

?4 summary operating plan for the plant is shown in tables

+3 (bagas:

fuel) and P-é (grass fuel) at the end of this

section. Each table is accompanied by a corresponding flow chart.

Phase II of this study will include a detailed operating

plan covering

ich two Weeks of the milling st

The operating plan for the plant is apportioned as follows:

as

---Page Break---

TABLE P-L

PROJECTED OPERATING PLAN

Calendar days per year operating days

ing Boen total total

Mina 16a 2182 got

Plant

Milling 473 9 182 ost

Non-mil-

ling season 136 7 163 ost

Subtotal 309 160325 ost

Maintenance

period - 40 40 -

Total 309 56 365, est

The plant will operate on bagasse and fallen cane trash the

equivalent of 164 days, and on energy grass for 145 days. tn General, the plant will burn sone grass during the milling season whenever the mill is down or if it is desired to accumulate bagasse in storage. Thus, grass will be burned at the beginning of the milling season and bagasse for sone days after the end. This means that the bagasse-burning period is not quite the same

as the milling period. However, their lengths should be about

the sane, so this distinction may appear in Phase I. The inte: gration of rice husks, pineapple wastes and other bionass fuels into the plan and the matter of fuel storage will be considered in detail in Phase 12 of this study.

Additional discussion of operating matters is found in the

?Supplemental Documents" of this report, including an extensive

86

---Page Break---

Giscussion and detailed estimates of the cost of rehabilitating

used PREPA To's.

4:6 Work to be done in Phases IZ and ir

The following matters will be included in phases II and IIT

of this report

2 Optimization (within the context of the Project) and

completion of the conceptual design of the plant, including:

* Desired average levels of output, when

milling and not mitzing.

* Spare capacity required to meet the needs of

customers and project operators.

© Capacity splitting, including ?new/usea"

alternatives.

© Availability and use of supplemental fuels

during the milling season, including rice

husks and pineapple wast.

© Fuel handling and storage facilities,

including alternate fuel flows (for example, mill

tana

to boiler, or through bagasse storage

faciisty).

© Integration of energy export capacity to the

PREPA system,

Borings at the power plant location, to

determine rock elevation and consistency.

». Evaluation of used 76's, including:

* Physical inspection of interiors.

---Page Break---

Preparation of documents required for final

on of U.S. Sugar Corporation

experience with used 76 (Note: used

PREPA boilers have been evaluated and found

unserviceable).

of power plant, including:

Environmental considerations; includiné

Plot plans and arrangement drawings

Plant heat balances

Plant piping flow diagrams

Electric one-line and instrumentation block

diagrans,

More detailed specifications for principal

items of equipment,

Final design and construction schedules.

Fertilizer runt off

Soll erosion

Herbicides and pesticide:

Reduction in airborne particulates

Tmpact of heavy equipment on soils

Improvenents to soil from better preparation and

more frequent planting.

Management and personnel

Financing and organization.

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TABLE Po3

FOWER PLANT

SUMMARY OPERATING PLANT = BAGASSE FUEL

(164 EFFECTIVE DAYS)

unit

Type

Average operating hour

Weight of fuel (as fired)?

Bagasse short tens

Fallen cane trash yw

Total noe

High heating value of fuel!

Bagasse million Brv's

Fallen cane trash " .

Total " .

Boiler efficiency

Steam produced at 950 psig, 900 deg F

Energy content million BIU's

BIU/Ib stean

Weight 2b

tProm Table M-5

4

Mumber

62

nm

527.2

219.0

66.2

8643

413.6

1,456

284,400

---Page Break---

Continued Table P-3 - page 2

eee

Steam extracted at 160 psig 415 deg F?

Energy content million BrU's 99.0

BTU/Ib stean 2,223

weight? ab 80,900

Steam extracted at 16 psig sat

Energy content million BTU's 83.8

BIU/1b 1,209

Weight? ib 75,600

Se

Steam condensed or lost

Energy content million BTU's 230.8

less electricity generated? " " 77.

Net " ? 153.6

BTU/1b 2,202

Weight ib 127,900

Electricity

Gross generation . 22,600

mill use . (2,900)

(900)

Export to PREPA 19,800

*allows for 10 peig pressure drop b

922,620 KW x 3,612 BTU/KW

? 44 x gross generation

95

jen rotor and Mill tanden.

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Continued Table P-2 - page 3

Se

elected rat:

Boiler stean/bionass a/b 2.00

Boiler stean/electricity Ib/gross KW 12.58

Electricity/biomass gross KW/ton aie

export Ki/acre 11,200

Average effective operating day (24 hours)

Weight of fuel (as firea)?

Bagasse short tons 2,483

Fallen cane trash . 24

Total 1,697

Electricity exports (rounded) Xi hours 475,000

(164 ettective operating days on cane biomass)

Weight of fuel (as firea)?

Bagasse short tons 243,200

Fallen cane trash 7 " 25.200

Total 278,300

Cane equivalent® short tons 590,400

Acreage equivalent (rounded) ® acres 6,950

Electricity exports thousand KWH 77,933

Gat 3,600 tons per eftective operating day

?nt @5 tons whole cane/acre.

96

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TABLE P-4

SUMMARY OPERATING PLAN - GRASS FUEL.

(245 DAYS)

unit

Type Number

Average operating hour

Weight of fuel (as tired)

?Energy grass: short tons 45

High heating vajue of tuet

Energy grass? nillion Bru 525.5

Boiler efficiency esis

Steam produced at 850 psig, 900 deg F

Energy content million Bru 336.3

Bru/Ib 1,454

Weight v6 231/300

ee

Steam condensed or lost

Energy content 5 million Bru

less electricity generated *

nee so

Bru/ib

Weight ab

ee

Jat 308 moisture

fat 11.6722 million Bruton

726,500 kw x 3,432 BTU/KW

---Page Break---

Continued Table P-4 - Page 2

Unit,

?Type Number

Electricity

Gross generation XW 26,500

Mill use ¢ * (200)

Plant use? * 1,100)

" $3300)

Export to PREPA

oe

Selected ratios

Boiler steam/bionass by 1b 2.57

Boiler steam/electricity lb/gross KW 8.73

Electricity/bionass gross Ki/ton 589

export KW/acre 13,000

een

Average effective operating day (24 hours)

Weight of fuel (as fired)

Energy grass short tons 1,080

Blectricity exports i 604,800

44 percent x gross generation

98

---Page Break---

Continued Table P-4 - page 3

unit

Type

9,in the milling season and

ling season)

Weight of fuel (as fired)

Energy grass short tons

Weight of fuel (as harvestea)>

Energy grass short tons

Acreage equivalent (rounded) ® acres

Electricity exports thousand Kwit

°at 67.4 percent moisture

Sat 59 tonsyacre

99

Number

156,600

336,300

5,700

87,696

---Page Break---

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---Page Break---

ECONOMICS

SECTION

---Page Break---

5.0 THE ECONOMIC ANALYSIS

5.1 Summary

Py the terms of the study proposal (1) optimization of the

Project's conceptual design is to be undertaken in Phase 11,

?Therefore, in Phase I, the Study Tean has sought only to deter-

mine if there exists at 1

bionas

tone fe

ible alternative for

commercialization at Canbalache.

More than anything else, the anewer to this question depends

on the answer to another question: whether or not the basic

Sectors of the Puerto Rican econony will start to grow again and

Grow fast enough so that PREPA must add new base-load electric-

Generating capacity within the next ten years. If the answer is

no, then this study should be terminated with Pha:

I. If the

answer is yes, then it should be completed, provided there is a

Feasonable chance that tax exemption and sufficient land can be

made available for the project.

Without adequate growth, PREPA's avoided cost (and therefore

ite maximum price for purchased power) will

jain around 5.4

cents Per kwh, the incremental cost of adding lead to its exist

ing oli-tired, ba

toad units. very fev, if any, alternative

energy Projects are feasible it they must sell energy to PREPA at
fhis price. Certainly the Canbalache Project is not one of then,

However, if growth ta adequate and new capacity must be added within ten years or so, PREPA'S avoided cost becones the Vite cycle cost of the most expensive unit it vould have to install in the absence of the Project. This could be in the Fane of @ to 10 cents per kwh. Depending on this latter nusber,

aon

---Page Break---

Cambalache and other projects may be attractive, particularly if initial investment per kw is substantially lover and/or specialized financing (such as Urban Development Assistant Grants) is available.

It is beyond the scope of the study to ansver the second

question, However, the critical numbers seem to lie between 3.0

and 4.0 percent per year in terms of real economic growth and 1.2 and 1.7 in terms of peak electricity demand. For example, if FREPA'S present forecast of 1.2 percent holds up, "there vill be

Ro need for additional generating capacity until the end of the

1990"

(22, p. 26). If the growth of peak demand approaches 2.0

Percent, new capacity on the order of 200 mw will be needed early

in the next decade (20).

Assuming adequate grovth in the demand for electricity, a

t

?ible design for the Project does exist. Many of its parane-

ters have been a

cribed and analyzed in the previous section:

?This section completes the tacke of Phase I by presenting and

analyzing the significant economic aspects. Key data from all four of these sections is summarized in Table E-3 following this text. For reasons explained subsequently, Table £-3 exclude: inflation, subsidies and taxes. The net cash flows on page tive of the table omit investment related charges. This is to facilitate calculation of present values, internal rates of return and similar measures.

Following are key results of the economic analysis

© Hithout the benefit of inflation or subsidies, the project generates 2 positive cash flow from operations beginning in the

---Page Break---

fourth year and for every year thereafter. For the Project as a whole, the net cash flow becones positive in the sixth year, vhen

construction is complete. Average annual cash flows fron Table

E-3 are summarized in the following table:

TABLE E-1

SUNMARY OF ANNUAL CASH FLOWS

operating periog Project

First Second life

We. 2s5 ve. 6-25 ve. 1-25

$000 $000 $000

operations (367) 4,227 3,312

Investment 6.920 1.388

Total (7,286) 4,227 1,926

Net cash outlays during the first five years of the Pro-

Ject's Life total $6.4 million, of which $34.7 million repre-

sents the initial investment and $1.7 million, the net loss from operations. During the 1

t twenty years, the annual cash flows

are positive and total $84.5 million, before inflation.

* Given the foregoing, the project not only recovers the

initial outlays of $36.4 million but also earns a return on these

expenditur:

equivalent to 12.2 percent in today's financial

markets.* Assuming tax exemption for the project, this return

pigyals the sun of the inflation-free internal rate of return of

Jyakabercent calculated from Table E-1 and investors?. current

average expections of future inflation of 4-5 percent, from ta)

---Page Break---

compares favorably with the 10 percent yield to maturity current~ ly quoted for PREPA bonds with a life of 20 years to redenp- tion.*# The corresponding inflation-free rates are 7.7 and 5.5 percent respectively.

@ Assuming project income is taxable, the return also compares favorably with the rate used by John S. Herald, Inc.

(98H) @ reputable firm of petroleum engineers and geologists, to

discount future operating profits from proven oil and gas re.

The comparable market rate, calculated from Table £-2, is 18 percent versus the 15 percent (before income taxes) used by JSH. The comparable inflation free rates are 7.7 percent and less than 9.9 percent respectively.

The JsH rates assume an increase in energy prices equi- valent to 4.6 percent per year compounded over the next twenty

sive

years, with other prices held constant. A more modest

sumption of a 2.0 percent annual increase yields a Project rate ef return of 11.1 percent and a JsH rate of less than 12.1 percent.

© By its sixth year, the Project will generate the equiva-lent of 563 direct full time jobs (50 weeks per year, 40 hours Per week), a5 shown below. The estimates bolow include transpor~tation and service of agricultural machinery and the transpor-tation of crops but exclude the transportation of sugar and

molasses.

**Source: Government Development Bank for Puerto Rico.

---Page Break---

TABLE E-2

EMPLOYMENT SUMMARY

Full-time

Planted Harvest equivalent jobs References

Sector acres interval Total Per 1,000 Section Tables

(mo.) acres.

Agriculture

cane 6.950 a2 17s a5 Bo ACL,A+2,Ax!

Grass 52700 6 23341 Bo AA3;ACa An

?Subtotal, 127650 407 E

crop transportation ?37 BYE Ari to a-g

(40 ton trucks) BL

Subtotal, 22,650 44a 38

Mill & Power Plant lis coms

?Total 563

Indirect enployment is estimated at 624 full tine equivalents and

total employment at 1,197, using type II multiplier of 1.52. for

agriculture, 1.70 for transportation and 4.93 for the mill and

Power plant (4, 1978, p.351).

Following are the nore important assumptions and conditions

used to obtain the above results:

© Except for the choice of "AY sugar and consideration of two TG's instead of one (Alternative Bon page 0), there has

been no attempt to optimize the Project

conceptual design. In

brief, there is room for improvement.

With the two exceptions indicated below, there are no

Price changes from 1984 during the twenty-five years of the

Project's life, Neither change assumes any change in the price of

Petroleum. Since both th

changes are structural rather than

inglation related, Table E-3 is

sntially in constant i984

prices.

---Page Break---

© The price of export energy incre:

from 5.3 cents/kwh in

year one to 9.8 cents/kwh in year ten, to reflect gradually the

increase in PREPA's "avoided cost" (See table E-3, page 5).

© The price of sugar declines from 22 cents to 11 cents, to

reflect the gradual loss of political power of the u.s. sugar

industry and the convergence of the domestic price to the ong-

run world price, estinated at 11 cents per pound (1984 terms) by

the World Bank. (See Table E-3, page 5).

© Throughout the Project life, agricultural yields average

no more than 70 percent of those obtained in field

cale and

fleld-plot tests during the AFE/CEER Bionass Energy Project (5).

© The industry receives tax exemption, but no subsidies. Tax

exemption is required for competitive reasons. There is no justification for subsidizing the Project, and the Commonwealth

cannot afford it in any ca

© Al1 inputs and outputs are valued at market pric

except irrigation water which is not sold commercially and is valued at the market price of the inputs required to put it on the crops. Tts cost at the edge of the field is estimated at 20 cents per 2,000 gations.

© The entire Project is

jumed to be undertaken by a single

organization which financ

the entire operation from its own

Fesources and at its oun risk (100 percent equity financing) .

* The mill is purchased by the Project on the firet day of

operations for $3.6 million.

other assumptions are found in the notes to Table E-3.

---Page Break---

hodology

For the purposes of this study, it is convenient to define

economics as the art and science which describes, analyzes and

evaluates those tradeoffs vhich can be expressed in nonetary

fers, Obvicusiy, money is not everything. However, the faculty

Of Sudgement breaks down vhen ore than four or five major

Shenents in a problem must be considered simultaneously. Hence,

At is useful to have techniques which reduce to a manageable size

?She nunber of elements quantifiable in monetary terms, for these tend to be numerous.

Projects such as the one under study are classic itlustra-
Stone of monetarizable tradeotfs, In this regard, they resesble thermodynamic syst.

that a project may be con-
ceived of as a systen with boundari

/ across which move energy and matter measured in terms of money as vel! as hours, tons and Bru

Mowaver, unlike the typical thermodynamic systems anal~
yeed in texts, no common physical denominator exists for flovs across the project boundary. There are too many different kinds of inputs and outputs

Moreover, project flows are dynamic, not

static. They are not bounded by nameplate ratings or efficient

Points on equipment curv

Instead, the pattern of project

flows Ss determined by a large number of external and internal

factors which may never be entirely known or predictanle.

Nevertheless, nost project flows do have money values as a

common denominator, for most (if not all) of the physical itens

Roving across the project boundary have a market price or a cost

based on these prices. Hence, for avery physical novenent, there

---Page Break---

exists an opposite monetary movenent, vhether simultaneous or

not. And for every pattern of physical flows over tine there

exists one or more "str

"of money flows. Typically, in the

Construction and startup periods, the net flow of funds is

negative each y.

an outflow. In the operating period, the

Feverse Bust hold true. There must be a net inflow, or the

Project will eventually go bankrupt. For example, in most

Periods, revenues from sales should exceed purchases of inpute

and Payments on account of debt, except perhaps for occasional

?baa? years or years of major expansion or replacenent. Hence,

Shere is usually a clearcut tradeoff to be measured, analyzed and

evaluated as one part of the economic and related analyses. we

must answer the question, do the net inflovs of later years

compensate for the net out flows of the early years and to what

exCent? Tf the answer is negative, the burden of justifying the

Project may be thrown upon those factors which cannot be nonetar-

ized.

At first glance, project evaluation would seem to be a straight forvard problem for » microcomputer spreadsheet progran, but in fact ie 4s not. Many questions, some of then difficult, Should be answered before data is entered.

© What prices should be used? The accounting values of the Project's sponsor? (These are usually a mixture of historical market prices, internal transfer prices, such ?standard costs", and accounting charges, such as anortization and depre-ciation). Warket prices? (These may not alvays exist or may be Gistorted by lack of competition, governnent regulation, etc.).

---Page Break---

OF "shadow prices"? (For example, market prices adjusted for subsidies, exchange rate distortions, market imperfections and/or social objectives).

What are the system boundaries at which flows are to be Reasured? The project itself? the sponsoring organization? The industry? ?The government? The municipality? the region? ?the country? or several of these?

@ When are money flows to be measured? when goods and services move across the system boundary? when an obligation to pay oF receive is incurred? (Accrual system), or when payments are made? (cash basis).

What is the appropriate rate of return which should be earned by the Project on its initial outlays, including invest ment and startup losses. should different rates be used for Public sector and private sector projects, or should the rate chosen depend primarily on industry-related or other factors

?The problem is complicated for several reasons. The project may

have unique features. Algo for several reasons long-term market

rates of return used as reference points usually incorporate sone
notion of what the long-term rate of inflation will be. this
latter rate may be wrong, or inappropriate for the project under
stuay.

© What alternatives should be considered for the long-term
financing of the project?

How is inflation to be handled? In the sensitivity analy-
sis? Or by incorporating differential rates of inflation for

10s

---Page Break---

?ch input and output into the stream of money flows and caleula-
Sing "future value" of the project, at the end of its 1ife?
Given all po:

ble combinations of the foregoing, it is
Possible to generate dozens of different streans of money
flows (i.e. spreadsheets) for each project, each one of which
Gescribes the project fro a unique viewpoint. Fortunately,

Shree or four vill generally suffice, unless there are many

financing alternatives which it is desireable to show separately.

5.3 Eeonomic cash Flows

?The study proposal provides for three separate sets of anai-

ys

~ scononic, financial and a cost-benefit - with one economic analysis to be included in the present Phase I report. taie anaiysis follows and is based on the feasible case summarized in Fable E-3 and on the assumptions stated previously. as noted, Prices are market prices or are based on the market cost of the relevant inputs.

The system boundari

are those of the Project, considered "2 single, autonomous, self-sustaining entity. The concern here is, can the Project as a project stand on its own?

As indicated in the titi

money flows are cash flows, re-

Frecting the timing of payments and receipts rather than the

Siming of movements of goods and services across the systen

Poundary, Or the creation of legal obligations to pay. The rates

of return are discussed in the following subsection. credit

financing is postponed for Phase II,

noted above.

tnflation is omitted from Table £-3 and discussed ube.

quently for

veral reasons. There is no rational basis for an

aio

---Page Break---

Andependent projection of the general rate of inflation more than

* few years in the future, Moreover, over the twenty-five years, the inflation rates for individual project inputs and outputs are Mable to diverge, and these divergences are liable to becone more important to the project than the general rate itself. (ror example, energy prices will probably rise faster than most other Prices). Projecting these individual rates is nore hazardous and uncertain than projecting the general rate. sy comparison,

aithough no standard methodology exists, it is

er and more
accurate to estimate investors? current expectations of future inflation and extract these from market rates of return. The adjusted market return is then compared with the inflation-free Project return.

As noted, the two price changes incorporated in Table £3 ate structural, not inflationary, and do not reflect any change in petroleum prices.

The price of electricity and the price of sugar are dis+ cussed in detail in ?Electricity Demand and Prices" and "suger Demand and Prices" following and in the section of "Supplenenta Documents" entitled "The World Market for Sweetners."

Table E-3 assumes that the cane nill is bought for $3.6 million (its opportunity cost to the Commonwealth) on the first Gay of the Project's lite, and that the remaining expenditures shown under "A, Initial Investment" are made in the middie of each year. The cane mill operates with its existing boilers and Surbogenerators during years one through five, the first oper-

ating period. Because of the small number of effective milling

---Page Break---

two and three, additional cane should be

shipped to Cambalache (or its cane and gress should be shipped

where) during those years. However, in order to reflect cash flows from project activities alone, Table E-3 shows the project as if only its own cane and grass were processed at Cambala- che. During years six through twenty-five, the second oper- ating period, the mill receives steam and electricity fron the power plant.

Note also that in the fourth and fifth years the Project makes a little money on energy cane alone. However, beginning with year six, such an arrangement would lose money. This shows clearly the need to create a new industry based on cane, rather than put "technological patches" on the traditional sugar industry.

5.4 The Internal Rate of Return

One of the ways to evaluate project is to calculate its internal rate of return (IRR). Thie is the rate of discount or appreciation which causes the stream of cash flows to sum to zero. Conceptually it is related to the tine preferences of human beings.

Most human beings prefer now to later. If they must post-

Pone something which they desire or need, they want to be compen-

ted for it. Hence, if delivery of a good or service lags behind the payment for the same by a significant amount of tine, adiscount may be called for (for example the prepublication discount on book

Conversely, if payment lags delivery, an

extra charge may be in order (for example, the finance charge on

12

---Page Break---

installment sales). similarly, charg

are made for the use of

another's money (interest) or another's goods (rent), for the

owner will not get (his or her) property back until sometime in

She future, And most people require sone (although not very

Buch) monetary incentive to save a little and a strong incentive

to save a lot.

The situation as regards the production of goods and ser-

vices for sale or exchange is more complex but not essentially

Gifterent from the above, in most cases. Almost every busin

regardless of size or economic system, has a continuous need for She services of things of value called assets, e.g. checking accounts, inventories, machinery, buildings. While some of these assets may be purchased on credit and/or rented, it is very rare in any economic system for enterprise to be able to finance and/or rent 100 percent of its asset requirements. Long-term wisks are greater in number, magnitude and uncertainty than short

term one:

So most people and organizations including prudent

bankers, Lessors and suppliers are adverse to indefinite conmit~

Rents to others and reluctant to enter into long-term ones, Fegardless of promises, fixed terns for payment and guarantees.

(Governnents, insurance companies, pension funds and venture capitalists are the principal exception.) Hence someone else

aust commit money to the enterprii

, But on an indefinite basis,

subordinate to the claims of others and subject to total to.

This is called equity financing, to distinguish it fron the

creait financing provided on specific terns by bankers or sup-

Pitere. However, even equity financing ia made in the hope of

---Page Break---

satning a return on, and securing the recovery of, the amount

invested. And, like any long-term commitment in a world of scar-

city, equity financing involves an opportunity cost to the

Provider, Indeed, many hybrid types of financing exist todav. so whether we rent, borrow or use equity financing, the basic elements of opportunity cost, risk and time are present.

From the above, it is apparent that this tradeott between She Present and the future, this time preference of human beings is @ natural phenomenon. it is not the invention of usurers on

?he exclusive property of some economic systen. Market rates of

interest on loans and financial paper, and long-run rates of return on equity investments attempt to reflect this trade-off, for different payment maturities, degrees of risk and other factors, with varying degrees of accuracy and fairness.

Hence, given enough stability in prices and in our expecta- Sions about inflation, any set of cash flows has an equivalence sf each point in time which depends basically on the rate (r) at vhich the analyst appreciates the past or discounts the future, fhat is, on his (or her) rate of tine preference. For example, fe determine the present value of stream of flows as of the first Gey Of & project Life of (t) periods, the cash flow corresponding Fe each periods is divided by (i+r)* and the discounted flows are Sunmed. Conversely, calculating the future value of a strean on She last day of the project requires each period flow to be appreciated, that is, to be multiplied by (1+r)*, The stream nay

be also evaluated at sor

intermediate point, say the first day

Of operations. In this cai

Prior periods are appreciated, and

us

---Page Break---

future periods are discounted. still another alternative is to find a value for (r) which makes the sum of the adjusted flows equal zero, at any point in time. This is the IRR, the internal rate of return on project investment.

As noted, the inflation-free IRR for the cash flows depicted in Table E-3 is 7.7 percent compounded annually. It is unique and Fealistic, That is, given the pattern of the net flows (first all negative, then all positive), there is no other rate which makes the sum of the tin

\djusted flows equal to zero. Moreover, the

net cash flows can be invested at rate 4)

existing financial
markets, as assuned by IRR method (6).

How such a rate should be evaluated has long been the subject of great controversy in the economics profession. several issues nave stood out: whether or not the cost of capital is independent of the mix of financing and under what conditions (7,8); whether rates for public projects should be higher or lower than those for private ones (9); and how to decompose observed market rates into components such as inflationary expectations, income tax, market risk, project risk and the "pure" interest rate (10,11).

The first is not relevant in Phase I, as a strict tost of 100 percent equity financing is imposed in this study. the Second has been made moot by the course of events. For example, multinational corporations, theoretically capitalist but actually controlled by their managers, have entered into joint ventures

with absolute monarchies and Marxist dictatorships, not to

mention numerous other (but less startling) hybrid forms of

---Page Break---

enterprise, At the same tine, wide variations in rates of return

on investment (12) and rat

ef technological change across industries have developed. In some electronics industries, a Product is obsolete in less than three years. Unit coste drop at rates of 20 percent per year or more, In others, such as the housing industry, handtools still predominate and productivity Growth is slow and difficult to attain. under the circumstances, industry rather than organizational criteria appear appropriate to evaluate the IRR of this project. In this case, the appro-priate industries are the energy industries, because the Project under study is primarily designed to replace o{1 in the expansion

Of PREPA's electric generating system. tn fact, by year six, approximately 60 percent of Project revenues are expected to be earned by the sale of electricity.

The third issue is relevant, however, since, Table E-2 uses constant prices, and the tuo structural price changes practically cance? out.* By contrast, observed long term market rates of return, whether for equity or credit financing, almost always include an expectation about the future rate of inflation, whether this expectation is accurate or not. one approach is to add an expected inflation rate to the IRR. Thus, it would be desirable to compare the IRR from Table E-1 with an appropriate market rate from which the expectation had been extracted or

alternatively, to add the expectation to the project IRR, as one.

{be geometric average of the Laspeyres and Paasche indexes of the Project's product prices (i.e. the Fisher "ideal" index) (13), Shows an average annual decrease of only 0.6. percent Gompound over the Project's 25 year life - 1.4% in the firss ton years and zero in the last fifteen,

---Page Break---

Unfortunately, there is no good way to measure inflationary expectations directly and serious doubts have been raised about the indirect method (10). For a long tii

it was believed that the "pure" (risk-free, inflation-free) rate of interest in the U.S. Was relatively stable and in the neighborhood of three percent. Thus, one could simply subtract the pure rate fron the

rket rate of interest for a relatively riskless security, such a8 U.S. Treasury bonds of a given maturity, to get an idea of what kind of inflation rate that investors were, on the average, expecting for the renaining life of the issue in question. However, for over fifty years, market rates of interest on financial securities have been much more stable than inflation rates, despite changes in marginal tax rates, which implies that the pure rate is in fact unstable. As for returns on equity investments, data problens make it difficult to say whether the Pure rate is stable or unstable. Consequently, the expected inflation rate of 4.5 percent used on page one was obtained im-plicity from an internally consistent forecast of GNP, interest rates and stock prices (2).

Stil] another approach is to take an evaluation of an appro-Priate energy-industry cash flow such as that of JSH which

incorporat.

fan inflation rate, apply the inflation rate to the

energy product prices in Table E-3 and st

how the resulting IRR

compa:

with the reference discount rate.

ous

umes that the individual company's price per barrel

of crude of1 will remain constant during 1985-88, then increase

to $75 per barrel by the year 2000 and remain constant there

a7

---Page Break---

after, Other prices and costs are constant at all tim

|. Taking

@ weighted average of the U.S. Department of Energy's ?actual

Gonestic average wellhead price" and its "average £.0.b. cost of crude oil imports" for 1984 (14, p. 89), which is $26.81, JSi's

jumption implie:

an annual rate of inflation in energy price:

Of 9 percent au:

1g the period 1989-2000. This is equivalent to a

constant rate of 4.6 percent for twenty-five yeare starting in

1986. Applying this rate of inflation to electricity prices tor

years four through 14 in Table E-2 gives an IRR of 18 percent for

the 1if@ of the project, which compares vary favorably with seH's

own discount rate of 15 percent, assuning both are subject to

income taxes at the s

rate. This confirns the economic feasib-

iLity of the project under the assumption of PREPA expansion.

?The comparison is even nore favorable than it looks because Producing oi1 from existing welle ie more risky than producing energy and other products trom biomass. goth activities, of course, use a mix of proven technologies or new technologies with

Proven component:

However, {1 production ie subject to a variety of royalties and production taxes, in addition to income

faxes. The former may be arbitrarily varied by governments and

cannot always be passed oato consumers. Also because of techni-cai problems in estimating of1-vell deciine curves (15), the future output of @ producing well cannot be forecast with the same accuracy as that of a biomass energy complex.

?A more modest assumption of a two percent annual increase in energy Prices gives a Project IRR of 11.1 percent and a JSH rate

of less than 12.1 percent.

aie

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5.5 Target Rate of Return

in the IRR calculation, the rate of return on investment is

the plug figure whos.

value is allowed to vary so that the cash

flows will sum to zero, i

0 the money flows will "balance",

3n the target rate of return (TOR) calculation, the price of some

input or output, in this case the price of electricity, is the

Plug figure and is allowed to vary so that revenues exactly

cover the economic cost of the project, including the cost of

capital at the TOR. this requires the procedure described in the

notes to Tables E-4 and £5,

?The TOR on investment is developed using the inflation-free equivalent of the PREPA rate. The inflation-free PREPA rate is

5:5 percent. Due to the novelty and increased complexity of the Project versus a conventional, oi1-fired generating station, a conservative investor might like to see a TOR, one quarter to one third higher, say at seven percent. Farmers would be charged 10 Percent on crop loans because of the higher administrative cost and greater risk of default.

At this rate of return, levelized annual expenditures per Table E-4 are $20.6 million, including investaent charges. Taking

non-electric revenues as given, the levelized annual required

revenue from the sales of electricity is $10.4 million, equiva-tent to 10.09 cents per export kvh as shown in Table E-5. this figure is higher than the year ten price of 9.8 cents per kvh of

Table E-3 for the reasons explained in footnote to Table E-5.

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5.6 Broduct Prices and Protect costs

tn today's world, growers and processors of agricultural raw

materials and sone food crops can no longer afford to think of themselves as mere producers of a bulk commodity or focus stub-Sornly on @ single end use. To do so is to condemn thenselves to the perpetual economic torture of wide price fluctuations, low

average pric

, overproduction, dumping and even the invasion of

their

kets by new products and/or new competitors. In brief, for nore and more grovers and processors, multiproduct output ie the key to biomass economics.

Moreover, it is typical of such operations that, anong variable costs, joint costs (incurred on behalf of several products) are more important than product-specific costs (incurred on behalf of only one product). Under these circumstances, the marginal-cost pricing so dear to economists is a sure road to bankruptcy. And fixed-percentag

-of-cost pricing so commen in Pusiness will lead to optimal prices only by rare coincidence. Instead, the

ler of the final products mst optimize their collective contribution to joint costs, both fixed and variable; fhat 48, optimize the difference between total revenues and total Product specific costs. In other words, the cane grower or

Processor must think of it

if it were a refinery or a slaugh-

Serhouse, with a valuable and verstile raw material to convert

into a "slate" of products whose numbe:

+ identity and character-

istics will vary from time to time as changes in market condi-

tions and technology dictate (16,17).

---Page Break---

A case at hand is the project under study. Table E-4 shows

an estimate of the percentace distribution of economic costs for

the Project in year eigt

when maximum gr

production is

Feached. Note that roughly 50 percent of total economic costs are variable and of these about 62 percent (or 31 percent of th.

total) are joint.

icity Demand and Prices

where in the world, the denand for electricity in

5.7

.

As el

Fuerto Rico is a derived demand. lect!

¢ energy is not desired

for itself but rather is an input to the production, distribution ©F consumption of other goods and services. As a result, changes in the demand for electricity depend primarily on changes in the

level and composition of economic acti:

ity. Price and income are not major influences on consumption, with two important exceptions. Even a modest increase in the cost of electricity (say 10 percent) has had, and may have in the future, 2 severe and Sonetines disastrous effect on businesses, such as hotels and

continous-process operations, whose

tric bills are already large in relation to their profits. Also, a change in the upper Limit of the residential subsidy, now at 425 kwh per month, would certainly affect household consumption inversely. However, as estimated in (18), the long-run price~elasticity of demand for residential consumers is only 0.33. That is, a 10 percent change in the cost of electricity produces an opposite change of only 3-3 percent in the anount of energy consumed. The incone elasticity 48 only 0.02, so that a 10 percent change in income translates into a 0.2 percent parallel change in energy use.

12a

---Page Break---

Tragically, for almost a decade, the Puerto Rican economy has been growing primarily on the basis of transfer paynents, especially those unrelated to the production of goods and services in any consumption period. This is shown in Table £-7. After a brief spurt following the 1973 oil crisis and the 1974-75 recession, the productive sectors of our econoay have essentially stagnated. This is shown by Table E-8. The foregoing plus population growth has caused unemployment to nearly double and remain at a high level, as shown by Table E-9. without a net migration roughly equal to the number of deaths, the situation would much worse.

A further consequence has been a decline in the consumption of electricity and the growth of excess generating capacity, as shown by Table E-10. As a result, PREPA'S "avoided cost" tor Purchased, base-load power is, at the moment, the incremental operating cost of its ofl-fired baseload units which is estimated at 5.4 cents per kwh for the purpo:

of this etuay (19).

At this price, almost no alternative to petroleum is attractive.

However, the present situation of Puerto Rico is dynamic,
Pot static. One way or ancther, it is liable to change markedly
before the decade is over. If Section 936 of the U.s. Internal
Revenue Code is eliminated, the economy of Puerto Rico will go

into a deep depression. smal1 island econonies, with too many

People and too few resources, far from large-volume, high-growth
markets, must import much of the funds which they require for

investment, regaraui

of their economic or political system. rt will take ten years, with no assurance of success, to reorient

322

---Page Break---

the industrial promotion program to Europe, Japan and Latin America. There is no way that wage credits can close the gap between Puerto Rico and its low-wage competitors, or supply the same volune of potential investment funds as Section 936". In this case, obviously, the excess of generating capacity will

increase rather than decre

If Section 936 is preserved but business and government go enacting as before, the present situation will continue to degenerate until it becomes intolerable for the poor of Puerto Rico and the taxpayers on the mainland. within a fev years, there will be a crisis of historic proportions.

However, the new Administration of the Commonwealth has given top priority to the creation of jobs and the preservation of Section 936. There is hope once again that the economy vill Grow on the basis of productive activity.

Economic growth, of course,

ans growth in electricity

consumption, albeit at a slover rate. Hence, if section 936 is

retained, an outcome such as shown in Table £-9 is possible.

Although not shown directiy, the implied grovth in total output

te about 4 percent per year compounded, before inflation. the

indicated growth in electricity concusption is about half of

that, 2.2 percent per year, as compared with an average annual

decres

©f 2.6 percent for last five fiscal years (Table £-6,

footnote one). Coincidentally, this is very close to the 2.0

Percent shown in PREPA's March 1984 forecast (20, Table 8). The

[remember of the study team worked on the three proposals to the

358; Congress to save section 931 and later replace it by Sect ine

936!

123

---Page Break---

corresponding peak-load forecast shows an annual grouth at a rate

Of 1.7 percent. (20, Table 8 and 21, Cuadro 4). This latter rate

Fequires addition of 300 mw of coal-fired, base-load capacity in

fiscal year 1993-94 and again in 1994-95 (21, cuadre 1). Also,

168 Mi of existing oil-fired capacity is to be reti

ed through

June 1994, for a net gain of 112 my. Varying the loss-cf-lead

Probability does not reduce the ve for new base-loag

capacity in 1993-34 (21, cuadro 6).

Given adequate growth in demand, FREPA's avoided cost will

shift to the life -cycle cost of a new generating unit by 1994.

an illustr:

ve estimate of this cost for 9 coal plant is shown

in Table E-i0, based on PREPA's 1982 study (23) and other sour=

ees. Although the estimate appears low, the figure of 6.6 cents

certainly makes alternatives unattractive, if only unit ?ife=

cycle cost is considered.

However, per Table E-10, the initial investment required tor

one unit is estimated at $600.7 million or 52,002 per gross kw,

in 1984 prices. The total investment for a three-unit, 900 aw

Generating station is estimated at $1.6 billion or $1,782 per

gross kw, with an annuai investment charge of abcut $223 mii}ion.

By comparison, the gross value of PREPA's total elactric plant in

service or under constru

1G, 2984 wan only $2.3

billion (historial cost), Moreover, after providing for current

expenses its total paysents to varicus funds in fiscal yoar

1983-84 as a result of contractual obligations were only $i9}

Rillion (24). Thus @ nove to coal, however attractive in teres

of life cycle cost, could strain the organization's gent

---Page Break---

service capacity, especially if electricity consumption grew nore

slowly than expected.

Table E-10 reflects the foregoing in part by using a capita

cost of 13 percent per year, instead of the 10 percent currentiy

sccepted by the Authority's bondholders. still, the magnitude of

the required investment is so great as to possibly be prohibi-

tive. Financing alternatives to bonds raise difficult financial

oF legal complications (25). Thus, PREPA may have to use alternatives with higher life-cycle costs but lower initial investments. In this regard, the Project's initial investment in electric plant, as shown in Table £-3, is only $969 per gross kw.

it is beyond the scope of this study to evaluate these

alternatives other than the Pro}:

at hand. Kevertheless, it is sate to say that their life-cycle costs should not exceed that of a new oil-fired plant, estimated at 9.8 cents per kwh in Table Eli, Therefore, for the purposes of this study, this latter Price is taken as the maximum price (in 1984 terms) which PREPA will ever pay for purchased power

Because of the long lead tines involved in most alternative ?energy projects, especially coal plants, it seens both fair and wise to phase in gradually the change in avoided cost. the critieal date in this regard Is not the date on which the new unit should enter ser

"@, but the last date on which # decision to

construct (or not to construct) can be made. In the case of

seal plant, this date may be only a few years away. Therefore,

the price of electricity in Table £-3 increases fron 5.4

per kwh in the first Project year to 9.8 cents in tho tenth

Ls

---Page Break---

Sugar Demand and Pri.

World consumption of sweetners is more than 122 aillion

short tons per year, of which 103 million shorts or less than 84

Percent is for cane and beet sugar, with a sucro:

content of 96

Percent in the raw forms. About 65 million tons or a little over

half of the world total is derived trom cane. corn sweetnere

account for less than nine per cent and other types less than

eight percent.

About 70 percent of the sucrose is consumed in the country

of origin and 10 percent is traded under preferential agreenents,

se only 20 percent is traded on vorid markets under anything

approaching competitive condition:

Demand tends to follow

Population growth and be relatively insensitive to changes in

prices and incom

+ From the producer's point of view, raw

Sugar is a bulk commodity with no neaningful distinctions between cargo

jeting trade standards for quality. all cane growers

face lead tines of twelve to eighteen months and, like most

farmers, are vunerable to the vagaries of disease, government

policy, markets, insects, and the weather. Many exporting coun-

?ries must aim for maxinun ales, almost regardiesa of price,

Because of the need for foreign exchange, the need to maintain

employment, lack of good alternative ui

for cane land and/or

inability to finance a switchover. overproduction is more common

than the opposite. World inventories currently stand at almost

fwice the desired level, and it will take at least five yoars to

Work off the excess.

---Page Break---

As a result, the world market for sugar is a residual market, in which most product nov

with export subsidies and/or is

sold at "dump" prices, frequently at a lo:

For example, a five

Percent surplus in world production can increase potential export supply by 25 percent. Reflecting such conditions, the current Caribbean price for ray sugar is less than three cents per pound, well below the 11 to 16 cents believed to represent the range of long-run cost for the world's most competitive mills.

over the long run, some recovery may be expected. In 1984, ?the World Bank used the long-run price of 11 cents per pound tor its project evaluations. However, this is still below the long-run costs of many producing countries.

The United States accounts for about 16 million short tons ef 13 percent of world swestner consumption, with over half supplied by sucro:

(including 6 million tons or 38 percent by

ane sugar). Forty percent is supplied by corn syrups and about

Seven percent by other eveetner:

In the U.S, and other indus-

*rialized countries high-fructose corn syrups (HFCS) are increas-

ingly displacing sucrose in its major uses, which are industrial.

Because of the political power of cane and beet growers and

Processors, the U.S. market is

mi-closed. An elaborate system

of loans, subsidies and trade restrictions fairly well limite

sugar imports to the U.S. production deficiency and maintains the

domestic price in the neighborhood of 21 cente per pound. The

latter price is, of cour

Well below the out of pocket cost of

Producing sugar in Puerto Rico by traditional methods, which

is estimated over 32 cents per pound. Moreover, there is no hope

327

---Page Break---

that Puerto Rico's traditional industry will ever be competitive

again. Nevertheless, as long as the U.S. price remains vel

above the world price, and there are other products to help pay

Ranufacturing costs, the possibility of making sugar in Puerto

Rico should not be discarded. at 21 cents per pound of 96

Percent pure raw sugar f.0.b the mill, a pound of sucrose in

sugar is worth over four tis

s its value as just another fernent-

able solid in A molasses, at 49 cents per galion c.i.f. San Juan.

The Puerto Rican market for sugar is estimated at 150,000 short tons per year of which 95,652 tons were provided from local

cane by the 1984 harvest and the rest inported.

Given the above and the large contribution to joint costs made by sales of electricity, production and sales of A sugar have been included in Table E-3, but at a price which declines fron 22 to 11 cents per pound in ten years. For a nore detailed comprehensive or overview of the Puerto Rican, U.S. and world sweetner markets, see ?World Sweetner Markets" in the ?Supple-Rental Documents" of this Report.

5.9 Mola:

\d_and Pri

The only continuous, organized markets are for blackstrap molasses (miel agotada or miel final), the residual liquid of traditional sugar manufacture by the three- (or four-) strike syste. As it cones from the centrifuges, this product 1 too viscous for pumping or consumption. Depending on end use, it is diluted with water to trade standards. For animal £1

4, apparent

soluble solids should be at least 79.5 percent (measured degr:

Brix) and total sugars (sucrose and others) at least 46 percent,

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both by weight. For the distillation of rum, the standards are 85 percent and 52 percent respectively, with 57 percent total sugars considered normal. During the harvest years 1971-80 in Puerto Rico, the median annual mill Brix was 88.4 degrees with a 90 percent range of 85.3 to 92.5 degrees. In practice, for various reasons, the true solids percentage blackstrap tends to be five to ten percentage points below the measured, but this Giscrepancy is less for sweeter types of molasses, such as A or high test.

The predominant use of blackstrap molasses varies greatly with geographic area, In the U.S. it is used primarily as cattle feed or as a feed ingredient (76 percent). In the Caribbean, it is the only legal feedstock for the distillation of rum, and in Brazil increasing quantities are used to make fuel-grade ethanol for gasohol. Minor uses include feeds for other farm animals and the manufacture of acetone, butanol, citric acid, compressed

ye

t, distilled spirits and pharmaceuticals. To complicate matters further, blackstrap competes in sone uses with molasses derived from sugar beets, citrus fruits or other raw materials: and statistics for the different types of molasses may be com mingled, or presented by weight or volume without giving equiva-

lencies. For example, mo}

es produced in Europe is derived fron beets and used largely for industrial purposes other than the manufacture of liquors. However, in recent years substantial quantities of this material has invaded the aninal feed markets traditionally supplied by blackstrap.

129

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World production of all xinds of molasses for industrial

purpot

tons, with Brazil, India, the Rus

for the crop year 1983-84 exceeded 33.3 million metric

ian block and the European

Economic Community accounting for

percent of the total. About

84 percent of all molasses is consumed in the country of origin;

in fact, exports declined 16 percent from 1977 to 1982, at an

average annual rate of 3.5 percent compounded. This reflects a long-term trend against molasses importers, as nore molasses is retained in the country of origin for animal feed and ethanol.

For the U.S. mainland consumption of all kinds of nolasses for all purposes in calendar 1983 is estimated at 653 million gallons, of which imports from foreign countries provided 276 million gallons or 42 percent. Puerto Rico consumption was 47.8 million gallons in fiscal year 1982-83, of which 37.4 million

gallons or 78 percent was imported at an average f.0.b. price of

36 cents per gallon. Of the balance of 10.6 million gallons, about 6.0 million was used for animal feed.* Estimated Project Production of 8.6 million gallons of molasses in year six is equivalent to 10.6 million gallons of blackstrap or 28 percent of Puerto Rico's 1982-62 imports.

Asa residual byproduct of a bulk commodity which is in World surplus, both long-term and short-term, blackstrap molasses aiso exhibits marked price fluctuations. From a high of 69 cents

Per gallon f.0.b. New Orleans in February of 1981, it fell toa

Puerto Rico Planning Board

130

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low of 6 cents in November of 1982; it then recovered to 41 cents

in october of 1983 where it re

ined until June 1984, dropping

gradually to 29 cents where it remained until June 1985. For the

purpos

of this Report, the A molasses price is based on a

blackstrap price of 30 cents per gallon f.0.b. New Orleans plus

25 percent for freight, plus a 23 percent premium over the c.i.f.

Price for its higher content of fermentable solids, plus a six

Percent premium on the adjusted c.i.f. price to represent the supplier's share of distillation economies. The latter include more alcohol per gallon of molasses and less distillation slops. These calculations must be refined in Phase II, particularly the last component of the A molasses price.

Since A molasses is @ nore desirable distillation feedstock than blackstrep, no insuperable technical difficulties are anticipated in convincing lecal rum distilleries to use the former to replace at least part of their requirements for the latter. Of course, the Bacardi corporation must continue to buy substantial quantities of blackstrap as it has made a substantial investment in an anaerobic digestor of advanced design to produce biogas for 100,000 pound per hour boiler. Thus, a minimum supply of distitiation slops, once considered to be only an obnoxious waste, is required at all tines.

The main problems foreseen in marketing project molasses are assuring security of the A molasses supply through long-term con-tracts and arriving at a mutually acceptable, flexible price

formula. These matters will be studied further in Phase Ir.

aon

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5.10 Sensitivity Analysis

?An important question in any project evaluation is, to what extent do key economic and financial results vary when an important assumption or parameter of the conceptual design changes? A complete sensitivity analysis of the relationships between

project variabl

and between th

and major assumptions will be undertaken in Phases IT and ITT of thie study. However, sone Preliminary observations can be made on the basis of the levelized costs and required revenues shown in Tables E-4 and E-5.

¢ The difference between the required price of export energy of 10.1 cents per kwh and PREPA's current avoided cost of 5.4 cents is critical. rt accounts for almost $4.9 million or 24 percent of the revenues required to cover the levelized cost of the project and is almost twice the capital recovery charge shown is Table E-5.

The project loses money out of pocket if the price of export energy falls below 7.5 cents per kwh, At that price, there is no contribution to a return on or the recovery of the initial investment. Below that price, there is not encugh

revenue from sales to cover operating expenditur

© Given the above, a critical and fundamental question is, will Puerto Rico's basic economic sectors begin to grow again.

Only if they do will PREPA's avoided cost incre:

to the point

where the Phase I version of the project is economically ?eas:

ble.

© A ten percent incré

je in the average cane yield per acre

will increase the delivered cost of cane about six percent and

432

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?the levelized annual economic cost of the project, about two

Percent. However, electricity exports, sugar revenues and

nol

18 xevenues should also increase, so the required price of

electricity should decline about 10 percent, to @.9 cents per

kwh. That is, a change in cane yields should produce an opposite

change in the required price of electricity of roughly the sane

magnitude.

@ Aten percent incre:

ein the average grase yield will
increase the delivered cost of grass about 5.5 percent and the levelized annual cost, about 1.2 percent. However, energy exports should increase about five percent, so the required price of electricity should fall about 2.5 percent. Increasing gras:

yields has much les

effect than incre

ing cane yields, so long

as grass is used only in the off season.

Aten percent increase in the target rate of return on

inv.

tment, from 7.0 percent to 7.7 percent, will increase the required price of electricity by only 1.5 percent. A 10 percent

increai

in construction costs will increase the annual econonic cost by 1.2 percent and the energy price by 2.4 percent. In brief, the required price of energy is relatively insentitive to changes in economic parameters relating to the initial invest-

ment.

A ten percent increase in the average price of sugar over

the life of the project will decrease the required price of

electricity by about seven percent, to 9.4 cents per kilowatt

hour.

---Page Break---

benefit from infl

@ The project is likely to obtain 1,

tion than a project with the same initial investment and revenu

where the latter are derived entirely from the sale of energy

Products. This is because the prices of sugar and molasses are

likely to increase more slowly than the general rate of infle~

tion, so the price of electricity must increase faster for the

two projects to show the same IRR in a given period. For example,

Af the general rate is ten percent and the rate for sugar and

nol

is five percent, the rate for electricity must be 13.5

Percent for project revenues to grow at the general rate. How-

ever, this is only liable to be a problen at high rates of infla-

tion which are precisely those most Likely to be caused by energy

Prices advancing faster than other prices. By the same token, the Project is less vulnerable to downturns in oil prices.

* Although major items of equipment are long lived, the Project is well-positioned to take advantage of possible long-run ehanges in technology on markets, such as changes in the type and

volume of fuels available, a molasses shortage in world markets, conmercialization of sucrose chemicals, conmercialization of enzyme decomposition of biomass, the use of sugar as a fuel Additive or increased demand for ethanol as a motor fuel, motor fuel component or @ turbogenerator fuel. The project boiler can burn a wide variety of biomase fuele or (with same modification) Coal, either alone or in mixture with biomass cane mill for a fuel supply. Sugar capacity can be expanded or eliminated at Bodest cost. With supplemental fuels during the milling seasons, Generating capacity could be expanded. A distillation unit, using

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50 peig steam for example, could

rr

ctions, the main thrust of thi

will be optimization and completion of the conceptual

5.11 Work to be Done in Pha

As indicated in previous

pha:

design in terms of all relevant criteria, This inclua

site

analysis, the preparation of all preliminary dravings, basic

specifications, construction schedules, operating plans, and

economic and financial projections required to perform tasks not included in the scope of the study. The latter includ

@ Pinal design

© Preparation of documents and specifications required for

contracting and procurement.

@ contracting, procure!

nt and the negotiation of long-term

contracts for supply product sales and financing.

@ Preparation of environmental impact statements.

Economic and related work to be carried out in Pha

HIT include the following:

Determination of economic 1ife, operating cost and mainte:

hance cost of equipment, machinery and structures to be installed

in the project.

Evaluation of the conceptual design fron the econonic,

financial and cost benefit points of view.

@ Evaluation of alternatives for the financing managexent, organization and ownership of project components.

as

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ena wavs

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Sretn SoBe Bite L9Lte sbory soa

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(924) (E9L) (651) (ava) (698) (WES) (E16) ¢ secusare

serwe pue Surrpuey e607

Ea otaen penuraveg - ¢ Fey

140

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Wotes to Table 5-3

A, Initial investment

2. AS put in place

Drainage

value of mila

Mi11 improvements

Power Plant

2. Cumulative average

B. Agricultural operations

1. Harvest areas

2. Harvest weight

3. Production costs

c. Transport

E, Industrial operations

1,2. Befective days

3. M21 0 and m expense

Power Plant o and =

ation

1, Output - electricity

= B sugar

Equals $68 per planted acr

Total column per "valuation of the canba~

che Mill in Supplementary Documents."

Total column per Table M-6, Section c.

Total column per Table P-2. Section d.

Asgumes mill bought on first day of Proj-

ect ?lite, other? investment expenditures

made at nid year of year indicated.

Based on Table A~6, Section 2.0

Base on yields indicated in Section 2.0

Based on above and Tables A-1 through A-, Section B. Use of working capital equals

subtotal x 704 x lo. Training and exeen=

sion expenditures assume 75 planted acres

Per farmer, $2,000 per new farmer per year,

3500 per farmer with one year or nore?o?

energy crop experience.

Equals harvest weight x $2.00 per short

ton.

Per Section D.

Per Table M-8, Section c.

Equals gross generation per tables P-4

Pos, Section D, x 0.6? cents per kwh.

Per tables P-¢ and P-5, Section D.

Calculated from table H-5, Section c.

aoa 90% of soluble

ine, 93% of these are ferment=

st of Late, \crose and 608 of

in Juice is extracted, Raw sugar 964

mi

---Page Break---

See Section E.

Handling and sales expense equals 6.

Fevenues fron sales of sugar and molas:

Exclude use of working capital, inflation

and [taxes to facilitate calculation of in

ternal rates of return, present values, et

Under varying assumptions about cost of cal

pital inflation and taxes.

---Page Break---

?TABLE E-4

LEVELIZED ANNUAL ECONOMIC COST OF PROJECT

$000" & Unit cost?

Agricultural operatio:

cane and trash? 7,142 34.5 $13.96 per short ton

of Whole cane

Grass? 4,410 21.4 $22.14 per

of Grass

Miscellaneous*

Subtotal 12,408 60.2

Transportation 2,220 $3.00 per short ton

of Bionase

cum. subtotal 4,628 72.0

Mi21 and Pover Plant 3487 16.8

cum. subtotal 1611s 8.9

Investment charges 2,500 a2...

Tota 20,615 100.0

Notes.

?calculated from Table E-3. The appropriate annual flow of ex- Penditures is first discounted to ?Project Year one at an? average nnual rate of seven percent compounded. ?The resulting presest values is then multipled by the. corresponding annual capital Eecovery factor of §.58 percent, to obtain the levelized annual economic cost.

270 obtain the levelized unit cost, the present value of the expenditures flow is divided by the? "present value" of the p= propriate flow of physical units, also discounted at seven per Gent.

jimcludes rental of land (at $50 per acre) and machinery.

?comprised of charge for use of working capital (10 percent per year on 70 percent pf production expenditures) and extension expense.

?Comprises only a seven percent return on and recovery of the initial invesment of $34.7 million. The corresponding expenditures: flow is not shown in Table E-3 but {s calculated as follows: Only interest is paid during ?the first five years. During the lact twenty years, the investment is amortized by an annual. capital

recovery factor of 9.44 percent. see also notes (3) and (4) above.

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TABLE 5,

LEVELIZED ANNUAL REVENUE REQOIRED

soogt ig Unit orice

?Revenues Crom sales

Electricity 10,809 50.5 10.09 cents per KWH

Suge: 1,265 35.2 13.34 cents per 1b.

A nolasse: 3,651 17.7 49.00 cents per galion

Handiing ané sales expens 7102 a.)

Net revenues 20,615 100.0

token

?me total is identical with the in Table £-8 sugar and solasses reve

ues are deterained as are levelized annual expenditury

in Table

Electric revenues are determined by difference.

?

determined a8 are unit costs in Table E-t, The unit price of export

energy 19 slighly higher than the highest price shown in Table B83

because, in Table E-5, working capital is changed for separately st 10

Percent? per year and amortization of the initial investment takes place

in 20 years instead of 25.

Sequals 6.5 percent of revenues froa 3

9 of sugar and & molasses.

14s

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DISTRIBUTION OF ECONOMIC costs

PROJECT YEAR EIGHT

Fixed

costs

¥

Agriculture? ??

cane 2

Gra 37

Subtotal, ?0

?Transportation -

Subtotal a

Cane Mill 0g mM 36

Power Plant 0.8 M70

Handling

and sales -

Investment

harqes?

charges 200

Total 50

TABLE E-6

Percent of item total

Variable costs

Specific

Joint

2

58

20

65

35

64

14

2

+

?3

21

35

23

16

100

as

?Total

*

200

100

100

100

100

100

100

100

100

100

Line Total

as § of

Project total

?

100

Tent of land and interest on working capital charges includea

in "Agriculture",

"Training and extension included in "Agriculture".

Srnterest and amortization of initital investment.

Source: Table £-3

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TABLE E-7

ROLE OF FEDERAL TRANSFER PAYMENTS TO INDIVIDUALS

IM PUERTO RICO'S ECONOMY

(CURRENT PRICES)

Fiscal year Ave. annual

1983-84 1973-74 change

$ millions § millions = 4

Transfers to individuals

Related to production of

goods and services in

Prior years 1,637 550 1.5.

Partially related? 186 17.8

unrelated? 1,267 50.7

Wot classified 1s:

Subtotal 3,076 607 a6

Less exployee contributions

50% Social security (337) (67) 9.0

civil Service retirement (4a) oy 8.8

Health & life insurance (2) ® 3.6

subtotal (429) a7 oat

Net 2,651 430 19.9

Bersonnal_inco:

Totai* 13,386 6,002 a6

Less non-Federal

?SStransfers 1991) (406) 93

Net 12,395 5,596 8.3

Ratio

Net Federal transfers

?to net personal income 21.4% 17 a

1a6

---Page Break---

Continued Table E-7

Not

1. E.g. Social Security, pensions

2. Medicaid

ALL other

After deduction of contributions to all forns of so-

cial insurance but before income tax.

Estimates calculated from: Anon. Informe Econémico al

Gobernador 1983-84" (Tomo 1), Junta de Planificacién de

Puerto Rico, San Juan, 22 de enero de 1985, Apéndice

tablas 8y 13.

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TABLE E-9

WORK FORCE

Fiscal year averages ave. annual

1983-84 1973-74 Change change

Births - number (000) 878

Deaths - number (000) (242)

Net migration? - number (000) 246

Population -

number (000) 3,270 2,878 392. ast

Working-age

(H/A) population?

number (000) 2,261 1,194 347 1.7

+ pop. 69.1% 66.58

Labor force

number (000) 952 847105 1.2t

¥ WA population® 42.18 44.38 (2.299

Employed

number (000) 742 744 @ -

4 W/A population 32.88 38.9% (6.1)?

Unemployed

number (000) 209 103106 7.38

2% W/A population 9.2 543.8?

& Labor force? 22-0 12.2 9.8?

Notes?

T

By differences

Fourteen years or older 1974; 16 years, 1984

Percentage points

Participation rate

Unemployment rate

Source: Anon, "Informe Económico al Gobernador 1983-84",

(Tomé 1), Junta de Planificacién de Puerto Rico?

22 de enero de 1985, Apéndice, tablas 22 y 23

ass

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TABLE E-10

STATISTICAL INFORMATION

PUERTO RICO ELECTRIC POWER AUTHORITY

Fiscal year Ave. annual

1983-84 1973-74 change change

(000) (000) (000) :

Ave. sales - xn? 1,159 2,185 (26) (0.2)

Ave. generation - KW? 1,402.1, 407 ?) -

Peak load ~ KW? 2,875 1,823 52 0.3

Dependable capacity -KW 4,207 3,080 1,127 3.2

Peak less installed 2,292 1,287 1,075 6.4

KW -¥ cap. 55.48 40,084.64 as

Notes

All-time high ave. annual

1983-84 Value change

.

* ave. sales - Kw 1,159 1,322 1978-79 (2.6)

% Ave. generation-KW 1,402 1,562 1977-78 (1.8)

3 Peak load - xw 1,875, 2,058 1978-79 (1.8)

$ Percentage points

Source: Puerto Rico Water Resources Authority

---Page Break---

TABLE E-11

A POSSIBLE FUTURE FOR PUERTO RICO

Fiscal year Ave. annual

1993-94 1983-842 change change

(000) (000) (000)

Population-number (000) 3,612 3,270 «342. 1.08

Working - age (w/a)

population

~ number (000) 2,589 2,261 328 ae

> * population 77k 69.18 2.6? 3?

Labor force

= number (000) 2,142 952 190,

~ BW/A population 44.18 42.18 2.03

Enploynent,

= number (000) 1,005 742263 3a

= # WA population 32.88 6.0

Unemployment

= number (000) 437 209 (72)

W/A population 5.38 9.28 (3.9)?

- # Labor force? 32,08 22.08 (10,0)?

Manufacturing

Enploynent®

= number (000) 208 142 65 3.98

= ¥ employment 20.78 91s a6?

Production ~ index 162 100 62? 4.98

Electricity consumption

(million keh)

Manufacturing 4,574 3,188 1,386 27

Residential 3,978 3,474 508 ee

other 4,030 3,493 537. La

Total 12,582 10,155 2,427 2.2

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Continued - Table E-11

Not

,zstinated from Anon, "ta Poblacién de Puerto Rico para el

Ako 2000", Junta de Planificacién de Puerto Rico, San Juans

de 1984, Tabla 1, and following assumptions of

labor force participation rate increases two per-

centage points inten years.

?Te unemployment rate decreases ten percentage points

in ten years.

* Dwenty-five percent of the net new jobs created are in

the manufacturing sector.

?tabor productivity in manufacturing increases at an

average annual rate of one percent compounded.

* Energy consumption in manufacturing increases at 3/4 of

the rate of output

* Residential electricity consumption increases at the

same rate as the working-age population.

Electricity consumption by other customers increases

at halt the rate of non-manufacturing employment,

Spercentage points

?The labor-force participation rate.

Stne unemployment rate.

SPer the household survey.

From Anon. "Informe Económico al Gobernador 1983-84" (Tomo

2), Junta de Planiticacién de Puerto Rico, San Juan, 25 °9e

Beto de 1985, apéndice tablas 23 y 24, and anon. ?Monthly

Report to the Governing Board ~ June 1984", ?October 1, ?isaa°

San Juan, p. 30,

asa

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TABLE E-12

LIFE CYCLE COST OF NEW COAL-FIRED

ELECTRIC GENERATING STATION IN PUERTO RICO

(2984 PRICES)

$ milion §/xwH

A. Initial investment

coal-pier 82.6 23

Unit No. 1 (300 MW W/scrubber) 517.3 1,724

"Mo 20m) 504.7 1,682

"Noam Hy goes 1,662

Total 2,603.9 1,782

Capital recovery factor (8) x 13.908

(38/yr, 240 months)

Annual investment charge 223.2

(5 million)

Annual net generation (ist)

(3 x 2,038.9 mm) = 6,116.7

Unit cost (cents/xKH) 3,687

Fuel expense unit Azount

Delivered cost of coal S/short ton 56.00

Efficiency KW/short ton = 2,400

unit cost cents KWH 2.333

Summary

Investment charge conts/ WH 3.667

Fuel expense ? 2.939

Operating and maintenance expense 0.592

Total 6.572

Kees: Estimated from Llavina, Jr. R. "A Status Report on

EREFA'S Coal Project," Puerto Rico Electric Power Authority, March 1982, 20 pp. and other proposals. for caribbean loca

153

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TABLE E13

LIFE-CYCLE ECONOMIC COST OF A NEW OIL-FIRED

ELECTRIC GENERATING STATION IN PUERTO RICO

(1984 PRICES)

Summary	unit	Amount
Annual investment charge	cents/KWH	3,599
Fuel expense?	"	5.662
Operating and maintenance expense	"	0.592
Tota		9.793

Not!

{assures 560 xWHt per barrel at $28.00 per barrel of No. 6 fuel git plus 19.2% "security premiua" to reflect maximum excess over spot prices which the Arabian-Anerican Oll Company's, private-sector partners appear willing to pay the Governsent Of Saudi Arabia, without strong protest.

Sources: Estimated from Llavina, Jr. R. "A Status Report on EREPA'S coal Project," Puerto Rico Electric Power Authority, March 1982, 20 pp. and other proposals for caribbean. lock?

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6.0 CONCLUSIONS AND RECOMMENDATIONS

Several important conclusions can be made about the differ-

ent areas reported on

lier.

?The agriculture component is feasible because new types of

energy Grass and cane have been developed for use in Puerto Rico

and Pecause the agriculture problem is one of reorienting the

?rowers and workers rather than of introducing new technology.

The important question, though, is can enough land be given over

fo this project to insure its success? About 7,000 more acres

must Pe found in Phase II before the Project can continue.

Although the mill itself has fallen into disrepair, a Getailed analysis has determined that it can be put back into working order for the reasonable sum of 3.4 million. The mill should be purchased fron the sugar Corporation before additional improvenents are made beyond the start-up phase. Further studies must be made concerning the true condition of mill equipment and the most advantageous milling procedures to be followed.

?The power plant can be operated on fallen cane trash, bagasse, and energy grass for more than 300 days to produce spough steam for the milling process and energy for export. Two siternatives concerning the turbogenerators must be studied further to guarantee that the most efficient procedures and

equipment will be used.

?The design presented in Phase I of the study appears to be

feasible in ai important respects, provided three conditions are pet:

ase

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© me bi

ic sectors of the economy of Puerto Rico will grow fast enough so as to require new electric generating capacity within the next ten years.

* Sufficient land for the project will be made available fron land previously committed to the Rice Project.

© The project will receive 100 percent tax exemption.

Hf there is a reasonable chance that these conditions can be met, it is recommended that Phases II and IIT of the study be undertaken innediately, for the following reason:

* The project can contribute substantially to reducing unemployment in the Arecibo area while making an important return an investment.

* There are obvious ways in which the project design can be improved, e.g. careful scheduling of planting, harvesting and transport; use of supplemental fuels during the milling season.

With or without modification, the traditional cane indus-

try in Puerto Rico is no longer viable.

© Creation of a new cane industry in Puerto Rico is a major option for agricultural development and petroleun inport subst i-tution which cannot be ignored.

Any island-wide study of this industry must include Cambalache ac ene of the locations for cane milling, whether or not it 4s finally selected.

© Im a complex study such as this, it is critical to sain-

?ain the monentun and cohesion of the project tean.

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