PHASE I REPORT

BIOMASS COMMERCIALIZATION 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

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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 all of the energy consumed on the island; and unemployment has leveled off at an unacceptably high percentage of the available work 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 Cambalache mill. The mill, which is located near Arecibo and which served an area of 300 square miles, was closed after the 1981 cane harvest for financial considerations.

The project under study proposes to create the full-time 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 CEER by a group of agricultural scientists who were more concerned with total tonnage of dry matter rather than with sucrose content. Several successful experiments have yielded up to 128 tons per acre of biomass and have demonstrated that biomass is a feasible alternative energy 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

Power Authority. The project will use equipment, technologies and crop management systems 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 problem.

This report is the final report for Phase I of the project. It covers the agricultural needs by describing the new varieties and projecting tonnage yields; it lists repairs and improvements 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 crops. The available land has dwindled from 15,400 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

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 a three-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 growers become more familiar with the energy management systems. The total land requirements for the Project are about 13,920 planted acres, or 15,310 acres in farm land allowing 10 percent for infield roads, drainage ditches, and structures.

Sufficient amounts of energy cane and grass can be grown in the Project area if proper attention is given to such problems as retraining, drainage, irrigation, and the need for changed work schedules. A top 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.

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

ments and repairs before the mill can be used, and $1.5 million in normal maintenance expenditures should be made during the first year. The Project assumes a target rate with traditional cane of 4,200 tons per day and a mill utilization rate of 90 percent. Since the mill will operate with cleaner cane, better maintenance and supervision, and less down-time 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 like $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 a 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 steam will be extracted from 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 315,000 pounds per hour of steam at 850 pounds per square inch with a calorific value of 1,454 BTU per pound of steam. The turbogenerator is of the double-extracting/condensing type with a planned output of 22,000 kw per hour when extracting for the mill. With 62 short tons of

bagasse 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 weeks of the milling season should be prepared in the next phase.

The report also 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:

1. 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.

3. 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.

4. 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 its debt service capacity if its moves to build a new coal power plant and

that the authority will have to add a new base-load capacity for 1993-94.

The demand and prices factors for sugar and molasses are also discussed in detail.

Conclusions and Recommendations

The design presented in Phase I of the study appears to be feasible in all important respects, provided three conditions are met:

- The basic sectors of the economy 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 immediately for the following reasons:

- The project can contribute substantially to reducing unemployment in the Arecibo area while making an acceptable return on the investment.
- 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 season.
- With or without modification, the traditional cane industry in Puerto Rico is no longer viable.

● Creation of a new cane industry in Puerto Rico is a major option for agricultural development and petroleum import substitution which cannot be ignored.

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

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

1.0 INTRODUCTION

1.1 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 employment 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 success. The taxes from rum sales are an important source of revenue for the Puerto Rican government. The rum industry, however, is threatened by a lack of sufficient domestic molasses, the basic feedstocks for rum production, from the local sugar industry. Foreign suppliers now provide about 90 percent of the molasses used in the rum industry. Dependence on imported molasses leaves the rum industry vulnerable to legislative action specifying a domestic origin of molasses 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 prices because of energy conservation and oil substitutes, future trends indicate that oil prices will

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rise as world oil consumption increase. This economic burden of importing oil for production of electrical power has placed a severe restriction on the Puerto Rican economy.

In the meantime, even with slow economic growth and continued efforts at energy conservation and oil 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 from 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 oil prices will begin to increase again and grow indefinitely at a faster rate time than other prices. In brief, oil 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 economy 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 domestic production of molasses for its viable rum industry, importation

of oil for almost all of its energy needs, and 22 percent unemployment. 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 unemployment.

1.2 The Cambalache Mill

The Central Cambalache mill is located a few miles from Arecibo on the north central coast of Puerto Rico. It ground sugar cane grown in the municipalities of Isabela, Quebradillas, 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 approximately in the middle of this area.

The area is a nearly level to sloping coastal plain and includes 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 1981, the main agricultural activities are dairy, rice and pineapple farming.

In the 1950's sugar cane was at the height of its reign in Puerto Rico, and the Cambalache mill was seventh largest of the 33 mills 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 interruption through the 1970's. Cambalache was last in the tonnage of cane ground of the seven mills still grinding in 1981, 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 Cambalache area.

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 molasses it needs, reduce its oil 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 Biomass 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 agronomically to produce one product only: sugar. These scientists removed the agronomic restrictions imposed by the sugar cane growers, and they allowed the cane plant to realize its full growth potential. In field experiments 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 tons 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. Also evaluated were tropical grasses such as Merker or Napier grass (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 Lajas experiments, 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 presentations to the Agriculture Commission of the House of Representatives 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. Jose 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 cane.

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 leaves) in an 18-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 with 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 grown and processed economically in the Cambalache area as a biomass energy crop to provide fiber for a boiler fuel for electrical production, molasses as a feedstock for the rum industry, and sugar for domestic consumption?

This report is the result of a proposal for a complete feasibility 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 Commercialization 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 Research (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 Municipality 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 contribution in kind of $4,300 from CEER. The primary tasks of Phase I are to determine if the project has a chance of being feasible and to make a preliminary assessment 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 for Phase I. It is accompanied by another document entitled "Supplementary 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 problems mentioned above. It proposes to create the full-time equivalent of 1,200 direct and indirect jobs by using 12,700 planted acres, the Cambalache mill, and a new power plant to be built adjacent to the mill to produce electricity, sugar and molasses from cane and Napier grass. 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:

TABLE I-1

SUMMARY OF PROJECT OVERVIEW

Component	Equivalent Direct (Number)	Initial ($000)	Inputs/yr	Outputs/yr
Farms				
Cane	174		6,950 planted acres	590,400 S.T.[1] whole cane 35,100 S.T. cane trash
Grass	233		5,200 planted acres	336,300 S.T. grass
Subtotal	407	860	12,650 planted acres	961,800 S.T. biomass
Transport	37		40 ton trucks	
Subtotal	444			
Cane Mill	107	5,544[2]	590,400 S.T. whole cane	35,500 S.T. raw sugar 8.6 million gallon "A" molasses 243,200 S.T. bagasse
Power Plant	12	28,292	243,200 S.T. bagasse 35,000 S.T. cane trash 156,600 S.T. dry grass	19,800 KW (milling season) 25,200 KW (off season) Power and steam to mill
TOTAL	563	34,696		

1. S.T. = Short Tons
2. Includes opportunity cost of mill to Commonwealth estimated at $3.6 million.

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Although the project will produce electricity, sugar and molasses, operating methods in each component will differ from those in the traditional sugar industry and electric utilities:

- The basic objective of agricultural operations will be to maximize biomass production per acre, not the sucrose percent of cane by weight or some similar criterion.

- The cane harvest will continue as long as weather permits.

- The "energy cane" and "energy grass" management systems 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 vehicles.

- 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" molasses (sweeter than blackstrap).

- The cane mill will receive its energy from the power 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) and a temperature of 900 degrees Fahrenheit.

● 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 will be extracted at 150 and 16 psig.

The project will use equipment and technologies which have been commercially proven in Hawaii, Puerto Rico and elsewhere or, in the case of the crop management systems, thoroughly studied in Puerto Rico. Even in the latter case, local farmers are familiar with most of the equipment and individual operations. Hence, 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 problem.

1.6 <u>Intended Audience</u>

This report is for the Municipality of Arecibo which wants to know if it is feasible to reopen the Cambalache mill for biomass commercialization. It is for the Puerto Rico Office of Energy to show the feasibility of continuing the study for Phases II and III of the Cambalache Biomass Commercialization Project. The report is for sugar cane growers in the Arecibo area and Puerto Rico in general to show them that sugar cane grown as an energy crop will allow them once again to grow cane as a profitable crop. This report is for the people of Puerto Rico for it offers them a chance to reduce their oil imports for electrical production, to produce sufficient molasses for their rum industry and sugar for domestic consumption, and to give employment to those people who will become part of the energy-cane sugar-energy

complex. Finally, this report is for those who doubt that sugar cane can be grown as a profitable biomass crop so that they can see that the concept is feasible.

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 generating this report is available in the "Suplementary 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 time 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 sections to achieve the objectives of 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 FIELD
GROWING
CUTTING WHOLE CANE
CANE TRASH
DRYING & BALING

ENERGY GRASS FIELD
GROWING, CUTTING
DRYING BALING

IRRIGATION

WHOLE CANE

SUGAR MILL

CANE MILL
GRINDING

BAGASSE

CANE JUICE

CLARIFICATION EVAPORATION

LOW PRESSURE STEAM

BAGASSE & GRASS STORAGE

BOILING HOUSE
GRANULATION

CONDENSATE

"A" SUGAR
"A" MOLASSES

TO MILL

STEAM (S)

POWER PLANT
STEAM GENERATOR
STEAM TURBINE
ELECTRIC GENERATOR

ELECTRICITY (E)

WATER (W)

ELECTRICITY TO P.R.E.P.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, Assistant 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 C. Jackson, Biomass Consultant

Cane Mill Section

   Mariano Romaguera, Engineer and Appraiser

Power Section

   Henry Ramos, Consulting Engineer

Economic Section

   Lewis Smith, Special Project Economist

AGRICULTURAL SECTION

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's 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 will be again (1). If Puerto Rico is to produce its own sugar and molasses in order to reduce its petroleum imports, it must create a whole new cane industry with fundamental changes in every component activity.

This section of the Phase I report discusses the agricultural activities and resources required to support the Cambalache cane mill and an adjoining power plant as one of several nuclei of a new cane industry which might be established in Puerto Rico. The principal innovations required in agricultural operations are:

● 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).

• Use storable biomass such as cane trash, energy grasses 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 cane" and "energy grass" management techniques. These 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 as a Renewable Energy Source," funded by the U.S. Department of Energy. Among the achievements of this project, a plant crop of 96 short tons per 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, Quebradillas, Camuy, Hatillo, Arecibo, Barceloneta, Manatí, Vega Baja, Vega Alta, Dorado and Toa Baja. This is approximately the area which the Cambalache mill served in the past; it reached a peak of 15,400 harvested acres in 1972. The mill is approximately in the middle of this area.

The area is a nearly level to sloping coastal plain and includes the alluvial flood plains along the Arecibo, Manatí and Camuy rivers. At present the main agricultural activities are dairy farming and pineapple farming. 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 grass. 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 inches. 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 meet the needs of the cane plant. An analysis of the amount of rainfall in relation to these needs shows that, on the average, there are deficits for the nine months from January to September, and excesses in November. These 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 area. The six leading soil types with approximate acreages are: Bayamón clay (9,900), Toa silty clay loam (6,200), Coloso silty clay (5,900), Almirante clay (4,900), Espinosa clay (3,700), and Bajura clay (3,200).

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 Bajura soils which percolate slowly 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.

2.3 Field Operations for Energy 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 biomass 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 fertilizer, especially nitrogen to nurture the cane to produce high tonnages; to use varieties that favor high tonnages rather than 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

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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 water availability are controlled.

The tillage sequence 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 smoothing 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 moderate 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 be a limiting factor. Existing canals will require renovation and new canals may be required. Flood gates and pumps will be needed on certain farms close to the ocean.

A network of mole and infield drains must be established to drain the root zone on slowly 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 a torpedo-shaped metal cylinder (4 inches in diameter) through the soil by means of a heavy tractor.

Final seedbed 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

soil. An additional step is the use of a rotavator, a tractor-drawn 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 emerge and grow.

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

The seed used will come 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 two to three inches 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 67-22-2, 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-biomass tonnage capabilities needed for energy cane. In some 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 required 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 II of the Project. Annual average requirements 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 fertilizer needs in Phase 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

of 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. Applications 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 own.

Insect control will be directed mainly at white grubs (the larva of Phylaphaga spp. and Diaprepes abbreviatus) major pests causing root damage; yellow aphids (Diaprepa abbreviatus adults) on cane folliage; cane stem borers and wireworms. Registered insecticides will be applied when necessary by tractor-mounted sprayers.

Replanting of cane or grass will be made 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 harvesting of cane with high tonnages (over 60 tons per acre) will require 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

cut cane into the trucks will be the boom-type with large grabs.
Large trucks, preferably 6 x 6 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
remains on the field (primarily dried fallen cane leaves) will
be raked, baled, and moved to storage areas for use as a supple-
mental 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 as soon as the cane trash has been baled and removed from
the field. The various operations include subsoiling, replanting
(if needed), irrigating as 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 similar to those for the plant crop.

2.4 Field Operations for Energy Grass

Another major element in the energy cane concept is the use
of alternate tropical grass species (primarily Pennisetum purpu
rem commonly known as elephant, Merker or Napier grass) as
supplementary biomass sources. During 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-

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 supplemental fuel for electric generation. The energy grass is ratooned five times 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 mower-conditioner. Besides cutting, it also shatters the stem, insuring an even faster solar drying. After cutting, the grass is windrowed 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 mowing, depending on the desired final moisture content, by using a baling system that makes 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 systems differ substantially from the old and must be understood and followed correctly. The best way to prepare 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

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growers who will be required to participate in this extension service program.

2.6 Land Requirements for Energy Cane and Energy Grass

The amount of land required for the production of energy cane depends on the capacity of Cambalache mill, its down-time, and the length of the milling season. Because cane must be ground within hours after harvest, the length of the milling season 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 downtime will be held to 10 percent, as discussed 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 acres 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, some agriculture land has been taken for business, housing, industry, parks, roads, and schools over the last several decades.

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This section estimates the approximate land needs for energy cane and energy grass production and the amount of suitable land that is available for the Cambalache Biomass Commercialization 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 considered 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 ratoons. Production using PR 980 with limited irrigation and some drainage problems 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 assumed 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 systems.

2.6.2 Length of the Cane Harvest and Milling Seasons

The length of the harvest season is mainly determined by the pattern of rainfall. The original planning for the Project cited an eight month maximum harvest season for energy cane as a possi-

bility (6), rather than the normal five-to-six month period typical of the sugarcane management system. 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 also has a poorly defined rainfall pattern as well. The latter problem 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 field work.

However, this rainfall pattern is not uniform. Dorado and Toa Baja have fewer field-work days than other municipalities; Manati has more. Hence, by planning and coordinating plantings and harvests, this difficulty can be minimized. However, a flexible work 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 to be 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.

This gives a milling season of 182 days or, with 10 percent downtime, 164 effective 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 Requirements 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 grass and other biomass must be available to meet emergencies during the milling season and supply the power 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 total 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

Land 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, 2,300; Manatí, 3,000; Vega Baja, 3,000; and Toa Baja, 3,000).

The identification of these 14,570 acres does not mean that this acreage is necessarily available for energy cane or grass production. Some of this land is now in housing, educational, school, commercial, and recreational areas. The land is, for the

most part, in farms now devoted to dairy farming and beef cattle production. The owners or lease holders of this land may resist the change from their present agricultural enterprise to 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 made available.

The Rice Project does have much suitable land for energy cane and grass production. Further study is 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 grass.

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 farms varies little by the length of the harvest season but is substantially influenced by yields. Cane production per acre for the "average" case is 22 percent less than that for the "good" case; grass, 20 percent less; but total requirements for land in farms is 27 percent higher. The acres in cane and grass respectively

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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 rehabilitate 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.

A top 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 Grass

Although it is difficult to estimate field production costs for an area where energy crops have not been grown before, good approximations are essential to calculate the economic feasibility of the Project. Depending on the cost of capital assumed, the delivered costs of crops account for about 65 percent of the total economic cost of products sold in year six of the Project, the first year of power plant operation.

Tables A-1 through A-5 at the end of this section show detailed cost estimates for each operation, for cane and grass respectively, by crop (plant and ratoon). To the extent possible, 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

equipment and land will be rented. Rental was assumed not only to simplify calculations but also because:

- On an equivalent basis, farm land is cheaper to rent for farm use 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 with equipment owners.

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

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

- In the time allowed, another internally consistent alternative 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 some farmers may favor more ratoons, production of energy crops falls off sharply as the number of ratoons increases, especially with irrigated cane, so as 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

short ton at the farm gate. Transportation costs from farm to mill are estimated to average $3.00 per ton. Total delivered cost is $1,405 per acre or $16.51 per ton. The most costly operations are harvesting, at $298 or $3.50 per ton, and irrigation, at $264 or $3.11. The highest material cost is 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 above.

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 estimated annual cost per acre for energy-grass production, based on 59 tons per acre per year from two crops, is $1,528 for the first year and $1,186 for each of the next two, at the farm gate. Per ton, this is $25.90 and $20.20 respectively. The cycle average is $1,300 or $22.03. The plant crop of energy grass costs $935 per acre or $31.70 per ton as compared to $593

or $20.10 for the ratoon crop. Highest costs are for irrigation and fertilizers. Harvesting costs at $68 per acre or $2.31 per ton, for mowing, raking and baling, are much lower 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, soil 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 meet the requirements for an energy-cane feedstock and those for energy grass as a 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 requires at least 15,000 acres of farm land, top priority must be given in Phase II to determine the availability of land and the impact of farm location 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 system.

• 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 times and storage methods for grass varieties to provide optimum 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 biomass collection.

• Define drainage and irrigation system requirements.

• Evaluate the possibility of row spacing wider than five feet to minimize machine damage to stools.

• Define fertilizer application techniques.

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 problem 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 schedules.

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 a new crop rather than repeat traditional sugar operations.

Table A-1

12 Month Field Operations - Energy Cane - Plant Crop

Operation	Passes	Equipment Type[1]	Hours	$/hour[2]	$/acre	Other Labor Type	Hours	$/hour[4]	$/acre	Other Expense Description	$/acre	Total $/acre
Tillage												
1 First harrowing	2	Rome 10-36 disk harrow, D-6 tractor.	1.00	$16.00	$16.00							
2 Liming	1	Lime spreader, D-4 tractor.	0.50	$9.00	$4.50					1 S.ton/acre @$12/S.ton	$12.00	
3 Plowing	1	Atlas 3-bottom hydraulic, reversible plow, D-8 tractor.	0.70	$18.00	$12.60							
4 Second harrowing	2	Rome 10-36, D-5 tractor.	1.25	$10.50	$13.13							
5 Land smoothing	2	Surveying equip., Marvin land plane, D-6 tractor.	1.00	$16.00	$16.00					Surveying	$75.00	
6 Spot leveling	[3]	D-6 bulldozer.										
7 Subtotal			4.45		$62.23						$87.00	$149.23

[1] Illustrative [2] Includes operator time, equipment transport, fuel and maintenance. Based on AFOA rates. [3] As needed.
[4] Includes fringe benefits.

Table A-1 (Continued)

	Operation	Passes	Equipment				Other Labor				Other Expense		Total
			Type[1]	Hours	$/hour[2]	$/acre	Type	Hours	$/hours[4]	$/acre	Description	$/acre	$/acre
	Drainage												
8	Preparation of mole drains	1	Single-shank 4" drain torpedo, D-8 tractor.	0.50	$18.00	$9.00							
9	Preparation of infield drains	1	Cleveland J40 trencher	1.40	$18.00	$25.20							
10	Preparation of intercept drains		See [9]	[3]									
11	Subtotal			1.90		$34.20							$34.20

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Table A-1. (CONTINUED)

		Equipment				Other Labor				Other Expense		
Operation	Passes	Type[1]	Hours	$/hour[2]	$/acre	Type	Hours	$/hours[4]	$/acre	Description	$/acre	Total $/acre
Final Seedbed Preparation												
12 Subsoiling	2	2-24" Subsoil shanks, 12" Duck-billed attachment, D-8 tractor.	1.70	$18.00	$30.60							
13 Rotavation	1	Rotavator, D-4 tractor.	1.25	$9.00	$11.25							
14 Furrowing	1	Furrowing disc, D-6 tractor.	0.70	$10.50	$7.35							
15 First fertilization	1	1-row, hopper-type attachment, D-4 tractor.	0.50	$9.00	$4.50					1000 lb 20-10-10 @$240 per Short ton	$120.00	$120.00
16 Subtotal			4.15		$53.70						$120.00	$173.70

36

Table A-1 (CONTINUED)

	Operation	Passes	Type[1]	Hours	$/hour[2]	$/acre	Type	Hours	$/hour[4]	$/acre	Description	$/acre	Total $/acre
			Equipment				Other Labor				Other Expense		
	Planting												
17	Seed placement	1	Seed cart, Wheeled tractor	1.25	$9.00	$11.25	Labor	2.50	$4.00	$10.00	3.5 S.ton/acre @ $25 per short ton	$87.50	
18	Covering seed	1	Disk harrow, 0-5 tractor.	0.70	$10.50	$7.35	Labor	1.00	$4.00	$4.00			
19	Replanting		Seed cart Wheeled tractor	[3]				[3]					
20	Second fertilization	1	Row, hopper-type attachment, Disk harrow, High-clearance tractor	0.70	$9.00	$6.30					700 lb 15-0-10 @ $164 per short ton	$57.40	
21	Subtotal			2.65		$24.90		3.50		$14.00		$144.90	$183.80
22	Irrigation		Pumps and spray rig	(see col.(11))			Labor	18.00 18.00	$4.00	$72.00	3 AC FT @ $64.00 ea.	$192.00	$264.00
	Subtotal												
	Pest control												
23	Weed control		Knapsac and Tractor sprayers	0.50	$9.00	$4.50	Labor	1.00	$4.00	$4.00	5lb/acre @ $7.00/lb	$35.00	
24	Insect control		See 23	0.50	$9.00	$4.50	Labor	1.00	$4.00	$4.00	8lb/acre @ $9.00/lb	$72.00	
25	Subtotal			1.00		$9.00		2.00		$8.00		$107.00	$124.00

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Table A-1 (CONTINUED)

	Operation	Equipment					Other Labor				Other Expense		Total
		Passes	Type[1]	Hours	$/hour[2]	$/acre	Type	Hours	$/hour[4]	$/acre	Description	$/acre	$/acre
	Harvesting												
26	Cutting	1	V-Cutter('coneja'), 180 hp Crawler tractor.	1.00									
27	Loading	1	Loader with 40 boom, Crawler tractor.	1.00									
28	Subtotal			2.00	[5]	$297.50							$297.50
	Miscellaneous												
29	Subtotal						Labor	2.50	$4.00	$10.00			$10.00
	Management												
30	Subtotal						Agron omist	10.00	$8.00	$80.00			$80.00
	Land rental												
31	Subtotal											$50.00	$50.00
32	Total												$1,366.43

[5] $3.50 per short ton X 85 short tons/acre

Table A-1 (CONTINUED)

	Operation	Passes	Type[1]	Hours	$/hour[2]	$/acre	Type	Hours	$/hours[4]	$/acre	Description	$/acre	$/acre
				Equipment			Other Labor				Other Expense		Total
161													
162													
163													
164	Operation	Passes	Type[1]	Hours	$/hour[2]	$/acre	Type	Hours	$/hours[4]	$/acre	Description	$/acre	$/acre
165													
166	Summary												
167													
168	7 Tillage			4.45		$62.23						$87.00	$149.23
169													
170	11 Drainage			1.90		$34.20							$34.20
171													
172	16 Final Seedbed												
173	Preparation			4.15		$53.70						$120.00	$173.70
174													
175	21 Planting			2.65		$24.90				$14.00		$144.90	$183.80
176													
177	22 Irrigation							18.00		$72.00		$192.00	$284.00
178													
179	25 Pest control			1.00		$9.00		2.00		$8.00		$107.00	$124.00
180													
181	28 Harvesting			2.00		$297.50							$297.50
182													
183	29 Miscellaneous							2.50		$10.00			$10.00
184													
185	30 Management							10.00		$80.00			$80.00
186													
187	31 Land rental											$50.00	$50.00
188													
189	32 Total			16.15		$481.53		36.00		$184.00		$700.90	$1,366.43
190													
191													
192													

Table A-2

12 Month Field Operations - Energy Cane - Ratoon Crop

Operation	Passes	Type[1]	Equipment			Other Labor				Other Expense		Total
			Hours	$/hour[2]	$/acre	Type	Hours	$/hours[4]	$/acre	Description	$/acre	$/acre
Harvesting of cane trash												
1 Raking	2	7-disk hayrake, D-5 tractor.	1.50	$10.50	$15.75							
2 Baling	1	Baler, D-5 tractor.	1.00	$10.50	$10.50							
3 Loading	1	Hydraulic fork-lift.	1.00	$14.00	$14.00							
4 Subtotal			3.50		$40.25							$40.25
Field maintenance												
5 Cleaning and reforming of infield drains		A-1/9 [5]	1.40	$18.00	$25.20							

[1] Illustrative [2]Includes operator time, equipment transport, fuel and maintenance. Based on AFDA rates. [3] As needed. [4] Includes fringe benefits. [5] Signifies, "see Table A-1, operation number 9".

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Operator	Passes	Type[1]	Equipment Hours	$/hour[2]	$/acre	Other Labor Type	Hours	$/hours[4]	$/acre	Other Expense Description	$/acre	Total $/acre
6 Subsoiling	2	A-1/12	1.70	$18.00	$30.60							
7 Furrow reshaping	1	2-Stool shaving implement, D-6 tractor.	1.00	$10.50	$10.50							
8 Replanting		A-1/19	[3]									
9 First fertilization	1	A-1/15	0.50	$9.00	$4.50					A-1/15	$120.00	
10 Second fertilization	1	A-1/20	0.70	$9.00	$6.30					A-1/20	$57.40	
11 Subtotal			5.30		$77.10						$177.40	$254.50
Irrigation												
12 Subtotal		A-1/22							$72.00	A-1/22	$192.00	$264.00
Pest Control												
13 Weed Control		A-1/23	0.50	$9.00	$4.50	Labor	1.00	$4.00	$4.00	A-1/23	$35.00	$43.50

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	Equipment					Other Labor				Other Expense		Total
	Passes	Type[1]	Hours	$/hour[2]	$/acre	Type	Hours	$/hours[4]	$/acre	Description	$/acre	$/acre
Operator												
harvesting												
Subtotal		A-1/28	2.00		$297.50							$297.50
Miscellaneous												
Subtotal						Labor	2.50	$4.00	$10.00			$10.00
Management												
Subtotal						Agron-omist	10.00	$8.00	$80.00			$80.00
Land rental												
Subtotal											$50.00	$50.00
Total												$1,039.75

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Table A-2 (Continued)

Operation	Equipment					Other Labor				Other Expense		Total
	Passes	Type[1]	Hours	$/hour[2]	$/acre	Type	Hours	$/hour[4]	$/acre	Description	$/acre	$/acre
Summary												
-------												
4 Harvesting of cane trash			3.50		$40.25							$40.25
11 Field maintenance			5.30		$77.10						$177.40	$254.50
12 Irrigation									$72.00		$192.00	$264.00
13 Weed control			0.50		$4.50		1.00		$4.00		$35.00	$43.50
14 Harvesting			2.00		$297.50							$297.50
15 Miscellaneous							2.50		$10.00			$10.00
16 Management							10.00		$80.00			$80.00
17 Land rental											$50.00	$50.00
18 Total			11.30		$419.35		13.50		$166.00		$454.40	$1,039.75

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Table A-3

6 Month Field Operations - Energy Grass - Plant Crop

Operation	Passes	Equipment Type[1]	Hours	$/hour[2]	$/acre	Other Labor Type	Hours	$/hours[4]	$/acre	Other Expense Description	$/acre	Total $/acre
Tillage												
1		A-1/7	4.45		$62.23					A-1/7	$87.00	$149.23
Subtotal												
Drainage												
2		A-1/11	1.90		$34.20							$34.20
Subtotal												
Final Seedbed Preparation												
3		A-1/16	4.15		$53.70					A-1/16	$120.00	$173.70
Subtotal												
Planting												
4		A-1/21	2.65		$24.90	A-1/21	3.50		$14.00	A-1/21	$144.90	$183.80
Subtotal												
Irrigation												
5		A-1/22					9.00		$36.00	A-1/22X1/2	$96.00	$132.00
Subtotal												
Pest Control												
6		A-1/25	1.00		$9.00		2.00		$8.00	A-1/25	$107.00	$124.00
Subtotal												

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	Operation	Passes	Type[1]	Equipment Hours	$/hour[2]	$/acre	Other Labor Type	Hours	$/hours[4]	$/acre	Other Expense Description	$/acre	Total $/acre
	Harvesting												
7	Mowing	1	Rotary scythe mower-conditioner.										
			D-6 tractor.	1.75	$16.00	$28.00							
8	Raking	2	A-2/1	1.50	$10.50	$15.75							
9	Baling	1	A-2/2	1.00	$10.50	$10.50							
10	Loading	1	A-2/3	1.00	$14.00	$14.00							
11	Subtotal			5.25		$68.25							$68.25
	Miscellaneous												
12	Subtotal						Labor	1.25	$4.00	$5.00			$5.00
	Management												
13	Subtotal						Agron omist	5.00	$8.00	$40.00			$40.00
	Land rental												
14	Subtotal											$25.00	$25.00
15	Total			19.40		252.28		20.75		103.00		579.90	$935.18

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Table A-4

6 Month Field Operations - Energy Grass - Ratoon Corp.

			Equipment			Other Labor				Other Expense		Total
Operation	Passes	Type[1]	Hours	$/hour[2]	$/acre	Type	Hours	$/hours[4]	$/acre	Description	$/acre	$/acre
Field Maintenance												
1 Cultivation	1	Cultivator knife										
		D-6 tractor	1.00	$10.50	$10.50							
2 First Fertilization		A-1/15	0.50	$9.00	$4.50					A-1/15	$120.00	
3 Second Fertilization		A-1/20	0.70	$9.00	$6.30					A-1/20	$57.40	
4 Subtotal			2.20		$21.30						$177.40	$198.70
Irrigation												
5 Subtotal		A-1/22					9.00		$36.00	A-1/22X1/2	$96.00	$132.00
Pest Control												
6 Subtotal		A-1/25	1.00		$9.00		2.00		$8.00	A-1/25	$107.00	$124.00
Harvesting												
7 Subtotal		A-3/11	5.25		$68.25						$68.25	$68.25
Miscellaneous												
8 Subtotal Management						A-3/12	1.25		$5.00			$5.00
9 Subtotal Land rental						A-3/13	5.00		$40.00			$40.00
10 Subtotal										A-3/14	$25.00	$25.00
11 Total			8.45		98.55		17.25		89.00		405.40	$592.95

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Table A-5

Crop Cycle Summary (Tables A-1 through A-4)

Operation	Energy Cane			Energy Grass		
	Plant Crop (Table A-1)	Ratoon (Table A-2)	3 yr. Ave.	Plant Crop (Table A-3)	Ratoon (Table A-4)	3 yr. Ave.
	$/acre/yr.	$/acre/yr.	$/acre/yr.	$/acre/6 mo.	$/acre/6 mo.	$/acre/yr.
Ratoons in Cycle			2			5
Expenses						
Field preparation and planting	$540.93		$180.31	$540.93		$180.31
Harvesting of cane trash		$40.25	$26.83			
Field maintenance		$254.50	$169.67		$198.70	$331.17
Irrigation	$264.00	$264.00	$264.00	$132.00	$132.00	$264.00
Pest control	$124.00	$43.50	$70.33	$124.00	$124.00	$248.00
Harvesting	$297.50	$297.50	$297.50	$68.25	$68.25	$136.50
Miscellaneous	$10.00	$10.00	$10.00	$5.00	$5.00	$10.00
Management	$80.00	$80.00	$80.00	$40.00	$40.00	$80.00
Land rental	$50.00	$50.00	$50.00	$25.00	$25.00	$50.00
Total	$1,366.43	$1,039.75	$1,148.64	$935.18	$592.95	$1,299.98
$ Short ton whole cane [1]			13.51			$22.03

[1] Assumes cycle average of 85 short tons/acre of whole cane, 59 short tons/acre of energy grass.

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TABLE A-6

ACREAGE REQUIREMENT FOR ENERGY CANE AND ENERGY GRASS

Cane harvest Calendar months	Cane season Effective days	Cane Milling season Eff. days	Non-Milling season Eff.days	Prod. requirements short tons/year Cane	Grass	Field production short tons/acre Cane	grass	Land required Cane	Grass	Total	Adj: Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Good production - with irrigation and variety US 67-22-2											
8	170	214	95	770,400	220,300	85	59	9,060	3,730	12,790	15,480
7	150	189	120	680,400	278,300	85	59	8,000	4,720	12,720	15,390
6	130	164	145	590,400	336,300	85	59	6,950	5,700	12,650	15,310
5	105	132	177	475,200	410,500	85	59	5,590	6,960	12,550	15,190
Average production - with limitations on drainage and irrigation, variety PR 980											
8	(same as above)					66	47	11,670	4,690	16,360	19,800
7	"	"	"	"	"	66	47	10,310	5,920	16,230	19,640
6	"	"	"	"	"	66	47	8,950	7,160	16,110	19,490
5	"	"	"	"	"	66	47	7,200	8,730	15,930	19,280

(1) Approximate

(2) Given

(3) Equals (2) x 7/5 x 90%

(4) Equals (365 days - 40 days x 95% - (3)

(5) Equals (4) x 3,600 tons/day

(6) Calculated from Tower Section, Table

(7), (8) See text, Agricultural Section

(9) Equals (5)/(7)

(10) Equals (6)/(8)

(11) Harvested acres. Equals (9) + (10)

(12) Acres in farms. Equals (11) x 110%

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2.11 References Cited

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CANE MILL SECTION
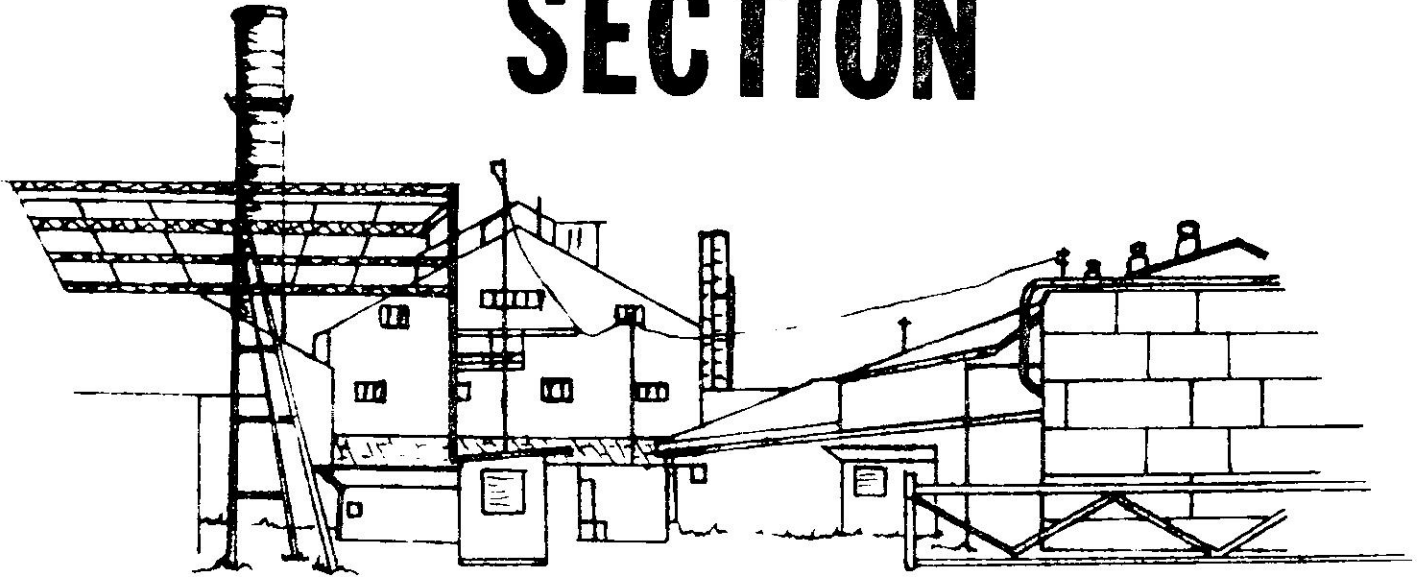
3.0 THE CANE MILL

3.1 The Need for Cane Milling

Most grasses can be cut or shattered, left in the field to dry and then baled for use. This is not so with cane even though it is a tropical grass related to corn, Johnson 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). Its principal constituent is water, as shown by the following table:

Table M-1

COMPOSITION OF CANE STALKS

	Energy Cane	Cambalache 1971-1980 medians (3)	Typical "sugar" cane (4)
Moisture	68 %	under 74 %	73-74 %
Fiber	17	16	11-16
Soluble solids	under 14	10*	10-16

*Equals (median percent pol 1971-80)/93%.

To complicate matters further, the most valuable compounds, fiber and sucrose, are intermixed, primarily in the stalk. For these reasons, 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 "cane mill" or, more commonly as a "sugar mill." For the same reasons, an understanding of both traditional and energy cane processing is necessary for an understanding of the Cambalache Project.

3.2 The Cambalache Cane Mill

The existing Cambalache cane mill 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) will be cut, crushed, shredded, and then milled in a 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 boiler 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 its 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 "blackstrap" (miel agotada or miel final). The sucrose, at 96 percent purity, will be sold as raw sugar to a 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 the juice, and hence, in the end uses of the molasses.

3.3 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 trucks and is unloaded Hilo-type unloaders. The cane then goes

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to a modern washing plant where it is cleaned in a Cording-drum pressure water-washing system. The juice is extracted by alternately wetting the cane with water and cane juice and then squeezing it between grooved steel rollers in a manner similar to wringing a sponge. The rollers are grouped in sets or "mills" (usually three per mill) and the mills (not to be confused with the entire processing plant) laid out in a row called a "mill tandem." The rollers are usually powered by steam turbines, steam piston engines of the Corliss-type (as at Cambalache), or electric motors. Prepared cane enters one end of the tandem, passes from mill to mill and comes 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 cleaner 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 50 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 (purification with lime and heat) to remove impurities.

• Evaporation of most of the water in the clarified juice, in a series of vacuum-boiling vessels known as multiple effect

"bodies" or "evaporators," to produce a syrup (<u>meladura</u>) of about 65 percent soluble solids and 35 percent water.

- <u>Crystallization</u> of the sucrose in the syrup in a vacuum-boiling vessel known as a "vacuum pan" (<u>tacho</u>) to produce a dense mass or "massecuite."

- <u>Centrifuging</u> to extract the sugar crystals in the masse-cuite. The residual viscous liquid may be watered to "A" molasses (as proposed in this study) or run through the last two stages two or three more times to extract more sugar and produce a weaker molasses (4). About 60 percent of the sucrose in the cane juice is extracted in the first pass or "strike" as "A" sugar.

3.4 The Importance of Crystallization and Centrifuging

In these stages, the recovery of the sucrose in the syrup is usually carried out by a cyclical process. These are critical steps because their efficiency will determine the amount of sucrose recovered and the amount left in the molasses in each strike.

The usual process in modern raw sugar production is the three strike 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 and molasses and also sugary water from the application of water in the process. The first two products are called first or "A" sugar and first or "A" molasses. The other half of the strike is fed with new syrup, first molasses, and washings.

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The first molasses then is moved to the second strike vacuum pan where another crystallization takes place with part of the output; the second or "B" molasses, is moved to a third vacuum pan. A similar process takes place for the third strike. The residual liquid is watered to make blackstrap or final molasses.

The centrifugation of the first strike is done immediately, 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 to 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 measured 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 otherwise be wasted because it is low-pressure steam (At 12-16 pound psig) from the exhausts of steam-powered mill equipment and vacuum-vessel vapors from multiple effect systems. Also, most steam and vapors are condensed and returned to the boiler as feedwater. However, with the three strike system, energy requirements for juice processing are large enough to require extraction of a significant amount of steam from the turbine section of the

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turbogenerator associated with the mill. This reduces the amount of electricity available for sale.

By contrast, when only one strike is made, the juice processing 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 number of strikes will be studied in detail in Phase II. Nevertheless, experience shows that, when energy prices are expected to increase and sugar prices to decline, one strike is probably enough. This assumption is used in this 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 immediately, and it should begin processing energy and conventional cane available while the power plant is under construction. Thus the boilers and turbogenerators presently in the mill would be used during years one through five of the Project; no grass would be used during this period because it is uneconomical with the old equipment. Tables 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:

M-3   Typical steam balance for three-strike sugar obtained by milling 4,200 tons per day of traditional 16 percent-fiber clean cane, with existing boilers and turbogenerators.

M-4   Typical steam balance for one strike ("A") sugar, obtained as in Table M-3.

M-5   Typical steam balance for one-strike ("A") sugar obtained from milling 3,600 tons per day of whole 18.6 percent-fiber energy cane (fiber equivalent of above clean cane), with new Power Plant.

In regard to these tables, note that from 1971 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 4,632 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 amount of whole energy cane is 3,600 tons.

Under the Project, the mill will operate with cleaner cane, better maintenance and supervision and less downtime than in the past. Also, juice processing will be considerably simplified by making only one strike. Therefore, the assumed rate of operation 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 Hawaiian practices. It is also important for the success of the Project. With new or rebuilt equipment, good management and good maintenance, 90 percent utilization is an attainable goal.

Mill steam requirements and energy available for sale under the three conditions are compared in the following table:

Table M-2

STEAM REQUIREMENTS AND ENERGY FOR EXPORT

Ave. steam requirements* (lb per hour, by pressure)	M-3	M-4	M-5
150 psig	80,900	80,900	80,900
16 psig gross	173,900	153,300	153,300
<u>less</u> exhaust	(77,700)	(77,700)	(77,700)
net	96,600	75,600	75,600
<u>Ave. export energy</u>			
(KW per hour)	-0-	735	19,800**

* Mill equipment only. Excludes electricity generation and turbine extractions.
** See Power Section, Table P-3

Obviously, there is a significant incremental benefit from reducing strikes. This may be seen by taking one strike as the initial condition. If several strikes are added, sugar extraction might be increased from 60 percent to 92 percent, or by 53 percent. However, net requirements for low pressure steam will increase by 27 percent, and energy for sale will decrease by 100 percent.

However, by far the greatest benefit comes from increasing boiler pressure 5.3 times 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 increases more than 25 fold. The main reason for this is that the energy in steam at these pressures has three components: the energy required to heat water to its boiling point (which increases with pressure), the energy required to transform water to steam (the energy of phase

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 incremental 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 Improvements 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 unloaders, and structural members such as the roof, have been severely corroded.

However, with proper improvements, repairs, and maintenance, the mill is capable of processing 4,500 tons of clean cane per day or 3,900 tons of whole cane. These matters are discussed in detail in the section "Potential Use of the Cambalache Mill for

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the Generation of Electricity," in the "Supporting Documents" section of this report.

The one-time improvements and repairs estimated to be required amount to $1.9 million and are summarized in Table M-6. This matter must, of course, be studied in much greater detail during Phase II. For example, the bearings of each tandem roll should be exposed and their condition evaluated. Nevertheless, Table M-6 is sufficiently accurate for the purposes of Phase I. In 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

Mill operating and maintenance expenses are detailed in tables M-7, "Estimated Mill Payroll at Capacity Operation," M-8, "Summary of Payroll Expenses," and M-9, "Estimated Mill Operating and Maintenance Expense at Capacity Operation." Separate estimates of annual expense 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 assumed that the existing 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 power plant.

Although these estimates are considerably lower than historical experience in Puerto Rico, the new cane industry can and should attain these targets.

3.9 Value of the Cambalache Mill

The Cambalache cane mill is valued in the books of the Sugar

Corporation at approximately $5.9 million, of which the land accounts for less than $50,000 (7, p.55). However, the Corporation 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 all removable materials as scrap. In "Valuation of the Cambalache Mill" in the "Supplementary 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, Professional Engineer, as follows:

"After careful consideration of all factors involved in the valuation of machinery and equipment, fixtures and leasehold improvements, it is our opinion that the market value of the Cambalache Cane Mill, not counting land, as of November 1984, is on 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 removable things of value were sold for scrap, considerable expense would be incurred to make the land usable for some other purpose.

3.10 Work to be Done in Phases II and III

Work during these phases will include the tasks such as those described in subsection 6 of the next section.

TYPICAL STEAM BALANCE (SIMPLIFIED)

THREE-STRIKE FROM TRADITIONAL CLEAN CANE

CAMBALACHE MILL WITH EXISTING BOILERS AND TURBOGENERATORS

I. Composition of cane and bagasse

	Clean Cane Short tons	%	Bagasse Short tons	%
Water	3,104	73.9	737	50.0
Fiber	672	16.0	672	45.6
Soluble solids	403	9.6	43	2.9
Ash[1]	21	0.5	22	1.5
Total per day	4,200	100.0	1,474	100.0
per hour	175		61.4	

II. Heat content of bagasse[2]

BTU per pound	4,099
Million BTU per short ton	8.199
per day	12,085
per hour	503.5

III. Requirement for steam at 150 psig, 415 deg F

A. Six-mill tandem

(28 short tons of fiber) x 110 hp/ton
x 25 lb/hp x 105%   lb/hr   80,850

B. Electricity generation (for Mill use only)

(175 short tons of clean cane) x
12 kw/ton x 135% x 40 lb/kw   113,400

C.   Subtotal   lb/hr   194,250

D. Boiler auxiliaries

1. Forced draft blowers

Subtotal III.C. x 1.65%   3,205

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[1] Non-combustible solids.

[2] High heating value per Hawaiian version of Hessey's formula.

    2. Boiler feed water system and emergency
       live steam system

    Subtotal III.C. x 1.35%
                                          2,622

E. Emergency makeup steam

    Subtotal III.C x 5.5%
                                           10,683

F.   Subtotal   lb/hr 210,760

G. Losses

    1. Radiation

    Subtotal III.F x 10%
                                         21,076

    2. Other

    Subtotal III.F x 5%
                                         10,538

H. Total requirement for steam at 150 psig

    1. Average requirement
                                  lb/hr 242,374

    2. Operational flexibility desired

    Average x 10%
                                         24,237

    3. Peak requirement (rounded)
                                  lb/hr 266,600

    4. Boiler capacity installed
                                       354,000

    5. <u>Excess</u> capacity installed under peak conditions (rounded)

    354,000 lb/hr - 266,600 lb/hr
                                       87,400

I. Energy equivalent of average requirements

    1. Energy in steam
                                BTU/lb   1,227
                                  million BTU/hr 297.4

    2. Average boiler efficiency
                                  %   52%

    3. Energy required in fuel
                                million BTU/hr 571.9

    4. Energy in fuel[3]

    (61.4 short tons bagasse x 8.199 million BTU/ton)   503.4

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[3]Deficit of 68.5 million BTU to be made up by burning a supplementary fuel, e.g. 11 barrels of No. 6 (residual) oil fuel per hour.

IV. <u>Requirement for exhaust steam at 16 psig sat</u>

   A. Juice clarifier   lb/hr   13,230

   B. Pre-evaporator   126,000

   C. Vacuum pan makeup

       144,900 lb/hr - 126,000 lb/hr   <u>18,900</u>

   D.   Subtotal   lb/hr   158,130

   E. Losses

       Subtotal x 10%   <u>15,813</u>

   F. Total requirement for exhaust steam at 16 psig

      1. Average requirement   lb/hr   173,943

      2. Operational flexibility desired

         Average x 10%   <u>17,394</u>

      3. Peak requirement (rounded)   191,300

      4. Exhaust available from prime movers
         under peak conditions

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

      5. <u>Excess</u> exhaust steam under peak conditions (rounded)

         222,600 lb/hr - 191,300 lb/hr   lb/hr   <u>31,300</u>

V. <u>Requirement for hot vapor at 6-8 psig sat</u>

   A. Secondary limed-juiced heaters   lb/hr   18,480

   B. Vacuum pans   59,640

   C. Make up to secondary vapors from first body   <u>15,225</u>

       (first evaporator)[4]

   D. Total requirement for hot vapor

      1. Average requirement   lb/hr   93,345

      2. Operational flexibility desired

         Average x 10%   <u>9,335</u>

      3. Peak requirement (rounded)   lb/hr   102,700

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[4]Asumes vapor from first body (first evaporator) utilized for juice heating in primary cane-juice heater.

Continued Table M-3 - Page 4

    4. Vapor available from pre-evaporator under peak conditions (see IV B)

       126,000 lb/hr x 110% x 60% (rounded)   83,200

    5. <u>Deficit</u> of vapor available under peak

       conditions (rounded)[5]

       83,200 lb/hr - 102,700 lb/hr   <u>(19,500)</u>

VII. <u>Requirements for hot vapor at 3 psig sat</u>

    A. Primary juice heater   lb/hr   <u>34,860</u>

    B. Total requirement for hot vapor

       1. Average requirement   lb/hr 34,860

       2. Operational flexibility desired

          Average x 10%   <u>3,486</u>

       3. Peak requirement (rounded)   lb/hr 38,300

       4. Vapors from first body under peak conditions

         (rounded)   21,600

       5. <u>Deficit</u> in vapor available under peak conditions (rounded)

       21,600 lb/hr - 38,300 lb/hr   lb/hr (16,700)

[5]To be made up from excess exhaust steam (IV.E.5) by means of pressure reducing valve.

TABLE M-4

TYPICAL STEAM BALANCE (SIMPLIFIED)

ONE STRIKE ("A") SUGAR FROM TRADITIONAL CLEAN CANE

CAMBALACHE MILL WITH EXISTING BOILERS AND TURBOGENERATORS

I. Composition of cane and bagasse (see Table M-1)

II. Heat content of bagasse (see Table M-3)

III. Requirement for steam at 150 psig, 415 deg F

A.	Six-mill tandem (see Table M-3, III.A.)	lb/hr	80,850
B.	Electricity generation[1]		
	1. For mill use		
	(175 short tons of clean cane) x 12 kw/ton x 40 lb/kw		84,000
	2. For export (by difference)		
	735 kw x 40 lb/kw		29,400
C.	Subtotal	lb/hr	194,250
D.	Boiler auxiliaries and emergency makeup steam (see Table M-3, III. D and E)		16,510
E.	Subtotal	lb/hr	210,760
F.	Losses (see Table M-3, III. G)		31,614
G.	Total requirement for steam at 150 psig		
	1. Average requirement	lb/hr	242,374
	2. Operational flexibility (Average x 10%)		24,237
	3. Peak requirement (rounded)	lb/hr	266,600
	4. Boiler capacity installed		354,000
	5. Excess capacity installed at peak (rounded)		87,400

IV. Requirement for exhaust steam at 16 psig sat

A.	Juice clarifier (see Table M-3, IV. A)	lb/hr	13,320
B.	Pre-evaporator (see Table M-3, IV. B)		126,000
C.	Vacuum pan makeup		—
D.	Subtotal	lb/hr	139,320
E.	Losses (Subtotal x 10%)		13,932

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[1] Reduction is due to smaller loads on centrifugal, water pumps and other equipment.

F. Total requirement for exhaust steams at 16 psig

    1. Average requirement   lb/hr   153,252

    2. Operational flexibility desired (10%)   <u>15,325</u>

    3. Peak requirement (rounded) lb/hr   168,600

    4. Exhaust available from prime movers
       under peak conditions

       Subtotal III.E (this Table) x

          110% x 96% (rounded)   222,600

    5. <u>Excess</u> exhaust unde peak conditions (rounded)

       222,600 lb/hr - 168,600 lb/hr   lb/hr   54,000

    6. Reduction in average requirements

       vs. Table M-3, IV. F.1 (rounded)

       153,300 lb/hr - 173,900   lb/hr   (20,600)

V. <u>Requirement for hot vapor at 6-8 psig sat</u>

  A. Secondary limed-juice heater
     (see Table M-3, V. A.)   lb/hr   17,600

  B. "A" strike vacuum pan[2]   26,775

  C. Make up to secondary vapor from first body
     (first evaporator)   <u>15,225</u>

  D. Total requirement for hot vapor at 6-8 psig

    1. Average requirement   lb/hr   59,600

    2. Operational flexibility desired (10%)   <u>5,960</u>

    3. Peak requirement (rounded)   lb/hr   65,600

    4. Vapor available from the pre-
       evaporator under peak conditions
       (see Table M-3, V. D.4)   83,200

    5. <u>Excess</u> of vapor under peak conditions (rounded)[3]

       83,200 lb/hr - 65,600   lb/hr   17,600

    6. <u>Reduction</u> in average requirements
       vs. Table M-3, V. D.1 (rounded)

       59,600 lb/hr - 93,300   lb/hr   (33,700)

VI. <u>Requirements for hot vapor at 3 psig sat</u>

    (see Table M-3, VI)

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[2] Actually two pans will be used, in off-set cycles, but only one at a time will be drawing hot vapor.
[3] Must be vented to atmosphere

TYPICAL STEAM BALANCE (SIMPLIFIED)
ONE-STRIKE ("A") SUGAR FROM WHOLE ENERGY CANE
CAMBALACHE MILL PLUS NEW POWER PLANT

I. Composition of cane, bagasse and trash

	Whole Cane Short tons	%	Bagasse Short tons	%	Fallen trash[1] Short tons	%
Water	2,469	68.6	712	48.0	43	20.0
Fiber	670	18.6	670	45.2	171	80.0
Soluble solids	432	12.0	43	2.9	-	-
Ash[2]	29	0.8	58	3.9	-	-
Total per day	3,600	100.0	1,483	100.0	214	100.0
per hour	150		62		9	

II. Heat content of bagasse and trash[3]

BTU per lb	4,266	6,672
Million BTU per short ton	8.532	13.344
per day	12,653	2,856
per hour	527.2	119.0

III. Requirement for steam at 150 psig, 415 deg F

A. Six-mill tandem (see Table M-3, III, A.)[4]　　lb/hr　　80,850

B. Total requirement for steam at 150 psig[5]

　　1. Average requirements　　lb/hr　　80,850

　　2. Operational flexibility (10%)　　　8,085

　　3. Peak requirements (rounded)　　　88,900

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[1] Non-combustible solids.

[2] Two thirds of field production.

[3] High heating value per Hawaiian version of Hessey's formula.

[4] No change in the amount of fiber per hour.

[5] No steam or electricity generation in Mill. All energy used by Mill is obtained from Power Plant.

IV. <u>Total requirement for exhaust steam at 16 psig sat</u>

    1. Average requirement

       (see Table M-4, IV. F.1)   lb/hr   153,252

    2. Operational flexibility desired (10%)   <u>15,325</u>

    3. Peak requirement (rounded)   168,600

    4. Exhaust steam available from mill tandem
          under peak conditions

       80,850 lb/hr x 110% x 96% (rounded)   85,400

    5. Net requirements for steam

       a. Average (rounded)

          153,300 lb/hr - 80,900 lb/hr x 96%   75,600

       b. At peak (rounded)

          168,600 lb/hr - 85,400 lb/hr   lb/hr   83,200

V. <u>Requirements for hot vapor at 6-8 psig sat</u>
    (see Table M-4, V)

VI. <u>Requirements for hot vapor at 3 psig sat</u>
    (see Table M-3, VI)

TABLE M-6

IMPROVEMENTS AND REPAIRS TO MILL IN PROJECT YEAR ONE

No.	Item	No. of units	$ per unit	$(000)
1.	Retubing of existing boilers	3	180,000	540.0
2.	Replacement of galvanized iron sheets on roof (square feet) 85,000 x 30% =	25,500	9.00	230.0
3.	Repair carrier chains for cane and bagasse conveyors	lump sum		50.0
4.	Repair heat-retaining insulation on piping and pressure vessels (about 20% of total surface area)	lump sum		120.0
	Subtotal (Item 1-4)			940.0
5.	New "Silver C-5" shredder with 1,000 hp turbine drive (or heavy-duty electric motor) and substation			
	Equipment (delivered)	1	240,000	240.0
	Installation, foundation and feed conveyer	lump sum		32.0
	Subtotal (shredder)			272.0
6.	Fuel handling and storage facilities[1]			
	Conveyers for bagasse and/or chopped grass (lineal feet)	240	300	72.0
	Storage building (60 x 120 x 24) space and return conveyer	lump sum		244.0
	Subtotal (fuel facilities)			316.0
7.	Weighing scale	1	86,000	86
8.	A sugar centrifuges	3	90,000	180
	Subtotal (items 1-6)			1,794.0
9.	Overhead and inspections			
	Items 1-4,7,8	10%	121,000	
	Items 5-6	5%	29,000	
	Subtotal (overhead)			150.0
	Total (items 1-9)			1,944.0

[1]In addition to existing equipment. Does not include machinery for breaking up bales of grass.

ESTIMATED MILL PAYROLL AT CAPACITY OPERATION

No.	Position Description	Payroll $/Hour/person	$/Mo./person	Annual $
Administrative personnel[1]				
1	Chief engineer		2,330	28,000
1	Asst. engineer		1,670	20,000
1	Chief chemist		1,830	22,000
1	Asst. chemist		1,000	12,000
1	Electrical engineer (instrument expert)		2,170	26,000
1	Clerk	4.25		8,500
	Subtotal			116,500
Shift personnel (milling season)[2]				
Laboratory				
1	Laboratory analyst		800	18,200
1	Sampler	3.95		15,500
	Subtotal			33,700
Cane yard				
1	Foreman		850	19,300
1	Cane analyst/core sampler		800	18,200
1	Asst. analyst	4.15		16,300
1	Payload operator	4.50		17,700
2	Crane operator	4.25		33,500
4	Utility person	4.15		65,300
1	Utility person	3.85		15,200
	Subtotal			185,500
Washing plant[3]				
1	Foreman		700	15,900
2	Console operator	3.95		31,100
	Subtotal			47,000

[1] 50 weeks/year; 40 hours/week. All receive lodging as well, except clerk.

[2] Annual payroll for hourly personnel based on 164 effective operating days; 3 shifts/day; 8 hours/shift and no overtime. (For overtime see "Summary" at the end of table).

[3] Project Years one through five only.

Milling tandem

1	Foreman		800	18,200
1	Mill feeder	4.50		17,700
1	Operator	4.50		17,700
1	Oiler	3.95		15,500
1	Plate cleaner	3.95		15,500
	Subtotal			84,600

Filter, evaporation and vacuum pan stations

2	Vacuum pan operators		2,770	125,800
2	Vacuum pan asst.	3.95		31,100
3	Utility person	3.95		46,600
	Subtotal			203,500

Centrifugals and weighing station

1	Foreman		800	18,200
1	Assistant	3.95		15,500
3	Utility person/weigher	3.95		46,600
	Subtotal			80,300

Boiler station[4]

1	Foreman		800	18,200
1	Payloader operator	4.50		17,700
2	Boiler feeders	4.50		35,400
2	Bagasse handlers	3.95		31,100
	Subtotal			102,400

Electric plant[4]

1	Panel operator	4.50		17,700
1	Asst. electrician	4.20		16,500
	Subtotal			34,200

Miscellaneous

1	Welder		800	18,200
1	Mechanic	5.00		19,700
1	Repair shop asst.	4.25		16,700
1	Time keeper	4.25		16,700
1	Utility person	3.95		15,500
	Subtotal			86,800

[4]Harvest years one through five only

Machine shop personnel[1]

1	Foreman			
2	Lathe operator		900	10,800
2	Asst. lathe operator	5.00		20,000
2	Carpenter	4.50		18,000
6	Helper	4.25		17,000
		3.95		47,400
	Subtotal			
				113,200

TABLE M-8

SUMMARY OF PAYROLL EXPENSES

Summary

	Fixed expense $	Variable expense $	Annual average $
Project years 1-5[1]			
Administrative	116,500	---	116,500
Laboratory	18,200	15,500	33,700
Cane yard	89,200	96,300	185,500
Washing plant	31,500	15,500	47,000
Miling tandem	84,600	---	84,600
Filter, etc.	94,000	109,500	203,500
Centrifugals, etc.	33,700	46,600	80,300
Boiler station	69,200	33,200	102,400
Power plant	34,200	---	34,200
Miscellaneous	54,800	32,000	86,800
Machine shop	54,700	58,500	113,200
Subtotal	680,600	407,100	1,087,700
Overtime[2]	---	85,800	85,800
Subtotal	680,600	492,900	1,173,500
Fringe benefits[3]	238,200	172,500	410,700
Total	918,800	665,400	1,584,200
$/short ton[4]		1.127	2.683
Project years 6-25[5]			
Total	736,700	574,900	1,311,600
$/short ton[4]		0.974	1.980

[1] With existing boilers and turbogenerators.
[2] Equals total shift payroll x 10%.
[3] Equals last subtotal x 35%. Includes vacations.
[4] Based on 164 effective days/year and 3,600 tons/day of whole cane.
[5] Reflects closing of Washing Plant and transfer of energy production to Power Plant.

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TABLE M-9

ESTIMATED MILL OPERATING AND MAINTENANCE
EXPENSE AT CAPACITY OPERATION

	Fixed Expense $	Variable expense $	Annual Average $
Project years 1-5[1]			
Payroll expense[2]	918,800	665,400	1,584,200
Other operating expense[3]	248,100	179,600	427,700
Maintenance expense[4]	97,400	1,402,600	1,500,000
Total	1,264,300	2,247,600	3,511,900
%	36.0	64.0	100.0
$/short ton[5]		3.807	5.948
Project years 6-25[6]			
Payroll expense[2]	736,700	574,900	1,311,600
Other operating expense[3]	198,900	155,200	354,100
Maintenance expense[7]	73,000	1,052,000	1,125,000
Total	1,008,600	1,782,100	2,790,700
%	36.1	63.9	100.0
$/short ton[5]		3.018	4.727

[1]With existing boilers and turbogenerators.

[2]From Table M-5.

[3]Allocated in proportion to payroll expense.

[4]Allocated by difference. Total estimated independently.

[5]Based on 164 effective days/year and 3,600 tons/day.

[6]Reflects closing of Washing Plant and transfer of steam and electric generation to Power Plant.

[7]Annual average equals 75% of average for years 1-5.

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POWER SECTION
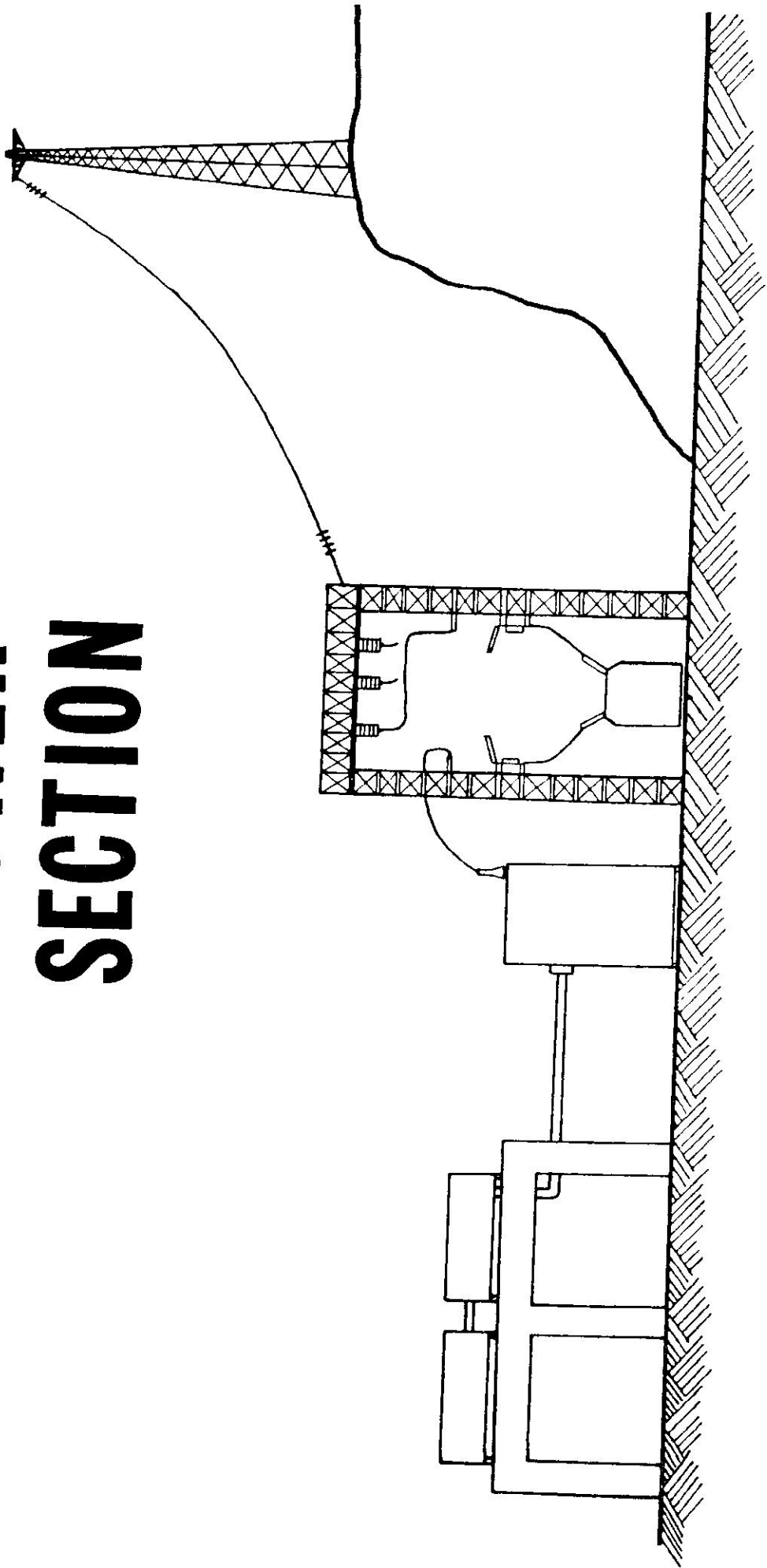
4.0 THE POWER PLANT

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 farms in the form of grass and cane trash, and from other sources such as rice husks from the rice farms. Using a high-pressure boiler, the plant will convert these fuels into steam which will in turn be fed to a turbogenerator 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, intermediate and low-pressure steam will be extracted from 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. If it is not so used, much of the heat value of the extracted steam will otherwise be lost in condensation.

The power plant consists of three main units - a boiler station, a turbogenerator (TG), and a switchyard - and a number of common facilities such as the plant building. The boiler station includes a boiler capable of producing 315,000 pounds per hour (lb/hr) of steam at a pressure of 850 pounds per square inch above atmospheric pressure (psig), a temperature of 900 degrees Farhenheit (deg F), and a calorific value of 1,454 British thermal units per pound of steam (BTU/lb), when oper-

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 steam is condensed. Electricity 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 equipment 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 estimated at $28.3 millon, excluding charges for the use of funds invested. Construction time -- including preparation of final designs, obtention of permits, erection of structures and the manufacture, delivery and installation of equipment - 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 availability of land, the physical composition of the cane to be processed, and the cost of storing fuel, taken together, impose definite limits on the conceptual design of the power plant. Furthermore, cane must be processed within hours of delivery to avoid decomposition of the sucrose and physical deterioration of the plant stalks. Finally, to assure the reliability of electric generation, the bagasse storage facility should be filled early

in 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-delivery rate plus the requirements for operating flexibility of the mill and the needs of the customers for electricity. In the traditional sugar industry, cane deliveries are often quite irregular and sometimes 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 design and operations. The capacity of the generating equipment may be considerably greater than the maximum supported by bagasse alone, including bagasse withdrawn from storage. In such a case, the generating capacity is likely to depend on a comparison of incremental (marginal) costs: that is, whether it is better to add a little more capacity to the biomass power plant or to some conventional fossil fuel generating station elsewhere.

However, the land requirements are still not known because of the commitment to the Rice Project. Therefore, to minimize land requirements in Phase I of this study, supplemental fuels were assumed to be available only for emergencies or during normal periods of mill maintenance. Furthermore, the harvest schedule will be developed in Phase II. For these reasons, the capacities of the boiler and generator in Phase I have been determined by the average expected deliveries of cane and fallen

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 report, 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 maximum calorific (high heating) value of 646.2 million BTU's. Under the boiler conditions described previously, this will produce 284,400 pounds per hour of steam. Boiler capacity is thus set at 315,000 pounds per hour, providing an operating margin equal to 10.8 percent. The capacity and other parameters of the TG follow from this and from the extraction needs. The TG capacity in turn determines 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 supplemental fuels. The tradeoff between larger equipment 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.

4.3 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. If properly operated, their performance is reasonably predictable. 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-

tween two TG's instead of one. In most biomass 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 I and will be studied in Phase II.

Because three TG's with a 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 Rincón Nuclear Plant, the possible use of one of these units in conjunction with a small new TG was evaluated as part of Phase I. As described in the "Supplementary Documents" of this report, detailed consideration was given to an alternative (Alternative B) comprising one used TG of 20,000 kw in conjunction with a new, double-extracting/condensing unit of 10,500 kw. The total capacity of Alternative B 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 supplemental fuels can be obtained during the milling season, Alternative B will be studied further in Phase II for the following reasons:

- The initial investment required for Alternative B in $32.1 million, 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 TG's instead of one.

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

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extracting/condensing TG takes away part of the savings made by the purchase of a used TG.

- Alternative B generates slightly more electricity for export than Alternative A, but most of this is during the non-milling season when the boiler is burning grass. Consequently, 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 I.

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

However, this matter will be studied further in Phase II. With the possibility of having supplemental fuel on a regular basis, two TG's (one used and one old) may prove attractive. Without supplemental 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 TG were estimated from budget quotations requested from manufacturers during the course of this study. Other items were estimated in relation to these and/or on the basis of ratios extracted from historial estimates 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 following:

Babcock & Wilcox International

Sterling Power Boiler design (VU-40S)

290,000 lb/hr

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

Combustion Engineering

Top-supported design (VU-40)

290,000 lb/hr

(c.i.f. San Juan) $5,500,000

The scope of supply for these quotations includes the boiler itself; air heaters; controls and instrumentation; an economizer; feed pumps and drives; a force-draft fan and motor drive; an induced draft fan and motor drive; a mechanical dust collector; mountings and valves; platforms, stairs and walkways; refractories, insulation and lagging; soot blowers with control panel; structural steel; a superheater; a travelling grate stoker with ductile iron links; spouts for bagasse feeding and export packing. The above quotations were scaled up to 315,000 lb/hr c.i.f. San Juan, allowing for economies of scale.

Budget quotations (c.i.f. San Juan) used for the TG included the following:

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 lb/hr, condensate lb/hr or kw as appropriate. The Brown Boveri estimate was also increased

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to reflect the fact that it was made when the exchange rate between the German mark and the U.S. dollar was about 3.0 to 1.0, compared to rates which seldom exceeded 2.5 to 1.0 in the period 1973-83 (1).

A closed loop, circulating water system with cooling tower is mandatory for the TG condenser. The prime source of water for this system is the nearby Rio Grande de Arecibo, which is 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 lost through evaporating and the systems will not be effected by river floods. The need for a water treatment plant will be studied in Phase II.

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. It 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 will 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 supply steam to the mill at two different pressures for two different operations. The mill tandem is a continuous operation subject to some fluctuation

and to occasional interruptions, planned and unplanned. This operation uses steam 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 time, there must be a much greater degree of coordination during the milling season than utility personnel are accustomed to. When a problem develops, one cannot simply take a boiler and TG pair "off the line" until someone figures out what the problem is and what to do about it. The mill cannot be left without steam while cane is being milled or juice is being processed.

Careful attention must be given to the recruitment, training, compensation, retention, supervision and periodic retraining of personnel. In a very real sense, the creation of a new cane industry in Puerto Rico is not an agronomic, financial or techno-

logical problem; it is primarily a management 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, more than 10,000 people learned to build refineries and petrochemical plants; more than 8,000 to operate them. At the peak of the industrial development program, some 300 of the more than 450 "four digit" manufacturing industries were represented by at least one establishment in Puerto Rico. It would be strange if people in agriculture 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 of experience in operating cane-based cogeneration systems at pressures of 800 to 1,250 psig, in seven different mills. The technology exists, and it can be used in Puerto Rico.

A summary operating plan for the plant is shown in tables P-3 (bagasse fuel) and P-4 (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 each two weeks of the milling season.

The operating plan for the plant is apportioned as follows:

TABLE P-1

PROJECTED OPERATING PLAN

| | Calendar days per year | | | Operating days |
	Operating	Down	total	% total
Mill	164	18	182	90%
Plant				
Milling season	173	9	182	95%
Non-milling season	136	7	143	95%
Subtotal	309	16	325	95%
Maintenance period	-	40	40	-
Total	309	56	365	85%

The plant will operate on bagasse and fallen cane trash the equivalent of 164 days, and on energy grass for 145 days. In general, the plant will burn some 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 some 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 same, so this distinction may appear in Phase I. The integration of rice husks, pineapple wastes and other biomass fuels into the plan and the matter of fuel storage will be considered in detail in Phase II of this study.

Additional discussion of operating matters is found in the "Supplemental Documents" of this report, including an extensive

discussion and detailed estimates of the cost of rehabilitating used PREPA TG's.

4.6 <u>Work to be done in Phases II and III</u>

The following matters will be included in phases II and III of this report:

a. 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 milling.
- Spare capacity required to meet the needs of customers and project operators.
- Capacity splitting, including "new/used" alternatives.
- Availability and use of supplemental fuels during the milling season, including rice husks and pineapple wastes.
- Fuel handling and storage facilities, including alternate fuel flows (for example, mill tandem to boiler, or through bagasse storage facility).
- Integration of energy export capacity to the PREPA system.
- Borings at the power plant location, to determine rock elevation and consistency.

b. Evaluation of used TG's, including:

- Physical inspection of interiors.

- Evaluation of U.S. Sugar Corporation experience with used TG (Note: used PREPA boilers have been evaluated and found unserviceable).

c. Preparation of documents required for final engineering of power plant, including:

- Plot plans and arrangement drawings
- Plant heat balances
- Plant piping flow diagrams
- Electric one-line and instrumentation block diagrams,
- More detailed specifications for principal items of equipment,
- Final design and construction schedules.

d. Environmental considerations; including:

- Fertilizer runf off
- Soil erosion
- Herbicides and pesticides
- Reduction in airborne particulates
- Impact of heavy equipment on soils
- Improvements to soil from better preparation and more frequent planting.

e. Management and personnel

f. Financing and organization.

TABLE P-2

INITIAL INVESTMENT REQUIRED FOR POWER PLANT
(WITH NEW BOILER AND NEW TURBOGENERATOR)

Division and Item	Type of expenditure $(000)			Unit location $(000)				Total $(000)
	Equip- ment	Instal- lation labor	All other	Boiler station	Turbo- gen.	Switch- yard	Common facilities	
1. Structures & Improvements								
Site improvements			88				88	
Piling			80				80	
Power plant building								
Substructure			285		285			
Superstructure			350		350			
Turbine pedestal			150		150			
Boiler station foundation			285	285				
Yard ducts & manholes			64				64	
Pipe trenches			39				39	
Condensate tank foundation			26		26			
Cooling tower foundation			103		103			
Intake structure			104				104	
Intake and discharge channel foundation			75				75	
Switchyard foundation			26			26		
Miscellaneous foundations			90				90	
Subtotal			1,765	285	914	26	540	1,765

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Continued Table P-2 - page 2

Division and Item	Type of expenditure $(000)			Unit location $(000)				Total $(000)
	Equip-ment	Instal-lation labor	All other	Boiler station	Turbo-gen.	Switch yard	Common facilities	
2. Boiler station equipment								
Boiler (c.-.f. San Juan)[1]	5,980	514						
Feedwater system	350	125						
Water supply & puri-fication system	108	46						
Cooling water system	112	26						
Piping	700	220						
Instrumentation & Control	350	125						
Fuel handling[2]	1,150[3]	300[3]						
Chimney	1,250	340						
Pollution control system	2,000	450						
Subtotal	10,850	1,846		12,696				12,696
3. Turbogenerator and related equipment								
Turbogenerator (c.-.f. S.J.)[3]	5,185	295						
Condensate water system	729	243						
Condensor cooling tower & piping	712	255						
Lubrication system	42	14						
Piping	122	39						
Subtotal	6,790	846		7,636				7,636

[1] Capacity of 315,000 lb/hr at 850 psig, 900 deg F and 64 percent efficiency.
[2] Included in Table M-5
[3] Output of 22,600 KW when extracting 80,900 lb/hr at 160 psig, 415 deg F and 75,600 lb/hr at 16 psig sat.
Nominal capacity of 29,200 KW without extractions.

Continued Table P-2 - page 3

Division and Item	Type of expenditure $(000)			Unit location $(000)				
	Equip- ment	Install. labor	All other	Boiler station	Turbo- gen.	Switch- gear	Common yard facilities	Total $(000)
4. Accesory electrical equipment								
Power plant service equipment								
AC	461	173			634			
DC	74	24			98			
Main relay & control panel	92	29			121			
Generator grounding equipment	9	2			11			
Conduits & wire	519	150					669	
Main generator leads	83	18			101			
Power plant grounding equipment	37	14			51			
Lighting equipment	80	28					108	
Misc. panels & controls	28	7					35	
Subtotal	1,383	445			1,016		812	1,828
5. Misc. turbogenerator equipment								
Compressed air system	67	18						
Sump pumps	12	4						
Fire protection system	32	11						
Communication & public address system	8	3						
Cathodic protection system	7	2						
Subtotal	126	38			164			164

Continued Table P-2 - page 4

Division and Item	Type of expenditure $(000)			Unit location - $(000)				
	Equip-ment	Install. labor	All other	Boiler station	Turbo-gen.	Switch-yard	Common facilities	Total $(000)
6. Painting								
Subtotal	30	7					37	37
7. Substation equipment								
38 KV Switchyard	231	46						
Transformers								
38 KV/13.8 KV	173	17						
13.8 KV/4,160 V	15	2						
38 KV/4,160 V	20	3						
Subtotal	439	68					507	507
8. Construction facilities								
Temporary buildings			30					
Services			30					
Equipment								
Office	25							
Transportation	30							
Laboratory	10							
Subtotal	65		60				125	125

Continued Table P-2 - page 5

	Type of expenditure $(000)			Unit location - $(000)				
Division and Item	Equip-ment	Install. labor	All other	Boiler station	Turbo-gen.	Switch yard	Common facilities	Total $(000)
Subtotal (divisions 1-8)	19,683	3,250	1,825	12,981	9,730	533	1,514	24,758
9. Other expenditures								
Consultants			200				200	
Design and general office work			550				550	
Freight, insurance and related[4]			937	536	274	48	79	
Other general			500				500	
Subtotal (division 9)			2,187	536	274	48	1,329	1,347
Subtotal (divisions 1-9)	19,683	3,250	4,012	13,517	10,004	581	2,843	26,945
% of total column	73.0	12.1	14.9	50.2	37.1	2.1	10.6	100.0
10. Contingencies (5%)								1,347
Total (Power Plant)								28,292

[4] Excluding those ocean charges included in the factory cost of the boiler and turbogenerator. Equals 11 percent of the balance of equipment expenditures.

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TABLE P-3

POWER PLANT
SUMMARY OPERATING PLANT - BAGASSE FUEL
(164 EFFECTIVE DAYS)

	Unit	
	Type	Number
Average operating hour		
Weight of fuel (as fired)[1]		
Bagasse	short tons	62
Fallen cane trash	" "	9
Total	" "	71
High heating value of fuel[1]		
Bagasse	million BTU's	527.2
Fallen cane trash	" "	119.0
Total	" "	646.2
Boiler efficiency		x 64%
Steam produced at 850 psig, 900 deg F		
Energy content	million BTU's	413.6
	BTU/lb steam	1,454
Weight	lb	284,400

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[1]From Table M-5

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Continued Table P-3 - page 2

Steam extracted at 160 psig 415 deg F[2]

Energy content	million BTU's	99.0
	BTU/lb steam	1,223
Weight[1]	lb	80,900

Steam extracted at 16 psig sat

Energy content	million BTU's	83.8
	BTU/lb	1,109
Weight[1]	lb	75,600

Steam condensed or lost

Energy content	million BTU's		230.8
less electricity generated[3]	"	"	(77.2)
Net	"	"	153.6
	BTU/lb		1,201
Weight	lb		127,900
Electricity			
Gross generation	"		22,600
less Mill use	"		(1,900)
Plant use[4]	"		(900)
Export to PREPA			19,800

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[2]Allows for 10 psig pressure drop between rotor and Mill tandem.

[3]22,630 KW x 3,412 BTU/KW

[4] 4% x gross generation

Continued Table P-3 - page 3

Selected ratios

Boiler steam/biomass	lb/lb	2.00
Boiler steam/electricity	lb/gross KW	12.58
Electricity/biomass	gross KW/ton	318
	export KW/acre	11,200

Average effective operating day (24 hours)

Weight of fuel (as fired)[1]

Bagasse	short tons	1,483
Fallen cane trash	" "	214
Total		1,697
Electricity exports (rounded)	KWH hours	475,000

Average milling season

(164 effective operating days on cane biomass)

Weight of fuel (as fired)[1]

Bagasse	short tons	243,200
Fallen cane trash	" "	35,100
Total		278,300
Cane equivalent[5]	short tons	590,400
Acreage equivalent (rounded)[6]	acres	6,950
Electricity exports	thousand KWH	77,933

[5]At 3,600 tons per effective operating day
[6]At 85 tons whole cane/acre.

SUMMARY OPERATING PLAN - GRASS FUEL
(145 DAYS)

	Unit	
	Type	Number

Average operating hour

Weight of fuel (as fired) Energy grass[1]	short tons	45
High heating value of fuel Energy grass[2]	million BTU	525.5
Boiler efficiency		x 64%
Steam produced at 850 psig, 900 deg F Energy content	million BTU	336.3
	BTU/lb	1,454
Weight	lb	231,300

Steam condensed or lost Energy content	million BTU	336.3
less electricity generated[3]	" "	(90.4)
Net	" "	245.9
Weight	BTU/lb	1,063
	lb	231,300

[1] At 30% moisture

[2] At 11.6722 million BTU/ton

[3] 26,500 kw x 3,412 BTU/KW

Continued Table P-4 - Page 2

| | Unit | |
	Type	Number
Electricity		
Gross generation	KW	26,500
less Mill use	"	(200)
Plant use[4]	"	(1,100)
Export to PREPA	"	25,200

Selected ratios

Boiler steam/biomass	lb/lb	2.57
Boiler steam/electricity	lb/gross KW	8.73
Electricity/biomass	gross KW/ton	589
	export KW/acre	13,000

Average effective operating day (24 hours)

Weight of fuel (as fired)		
Energy grass	short tons	1,080
Electricity exports	KWH	604,800

[4] 4 percent x gross generation

Continued Table P-4 - page 3

	Unit	
	Type	Number

Average year

    (145 effective days, 9 in the milling season and
136 in the non-milling season)

    Weight of fuel (as fired)

Energy grass	short tons	156,600

    Weight of fuel (as harvested)[5]

|		
Energy grass	short tons	336,300
Acreage equivalent (rounded)[6]	acres	5,700
Electricity exports	thousand KWH	87,696

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[5] At 67.4 percent moisture

[6] At 59 tons/acre

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4.8 References Cited

1. Corlett, O.S. "Understanding the Currency Game," Value Line Selection and Opinion, Arnold Bernhard & Co., New York, September 9, 1983, pp. 884+.

2. Reason, J. "On-the-Job Training is No Training," Power, June 1983, pp. 85-87.

ECONOMICS
SECTION
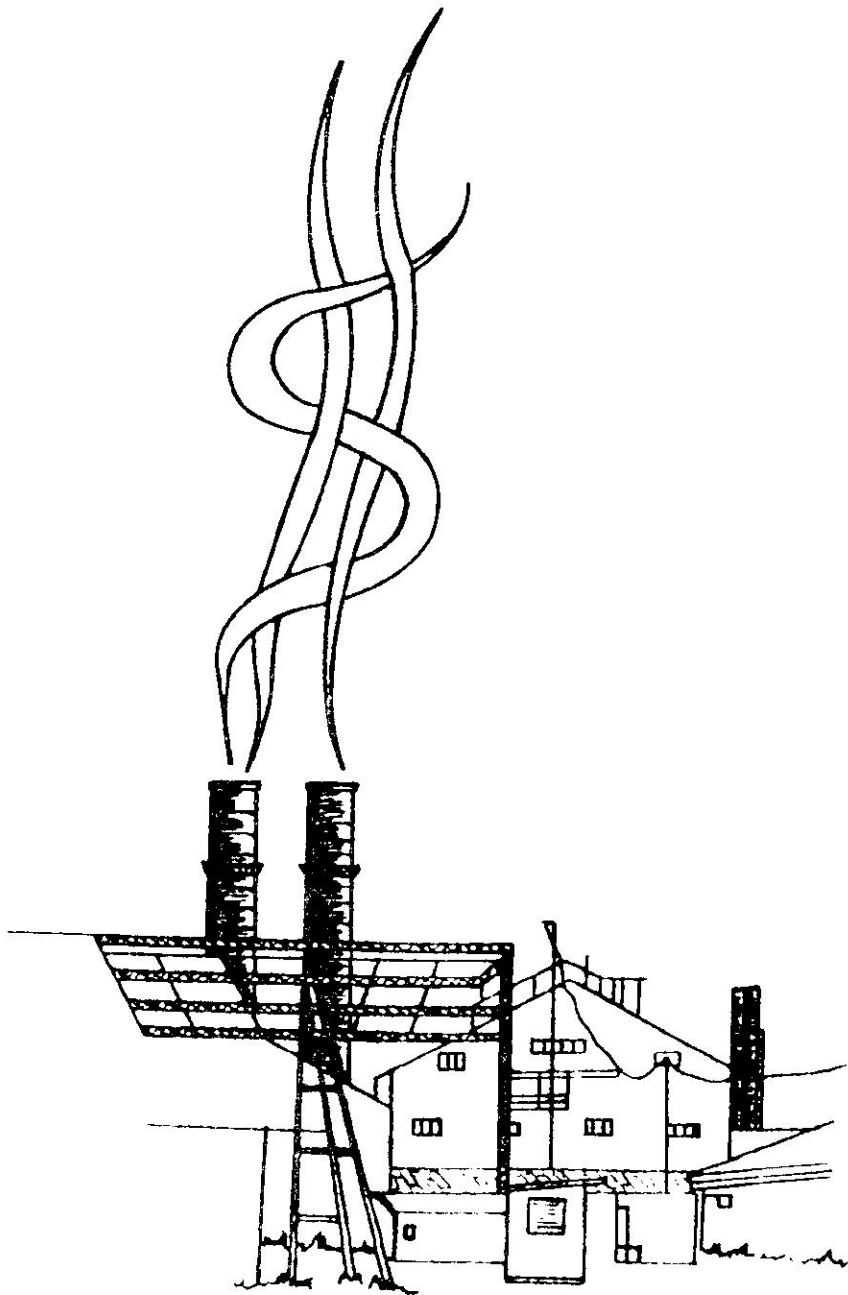
5.0 THE ECONOMIC ANALYSIS

5.1 Summary

By the terms of the study proposal (1) optimization of the project's conceptual design is to be undertaken in Phase II. Therefore, in Phase I, the Study Team has sought only to determine if there exists at least one feasible alternative for biomass commercialization at Cambalache.

More than anything else, the answer to this question depends on the answer to another question: whether or not the basic sectors of the Puerto Rican economy 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 Phase I. If the answer is yes, then it should be completed, provided there is a reasonable chance that tax exemption and sufficient land can be made available for the project.

Without adequate growth, PREPA's avoided cost (and therefore its maximum price for purchased power) will remain around 5.4 cents per kwh, the incremental cost of adding load to its existing oil-fired, base-load units. Very few, if any, alternative energy projects are feasible if they must sell energy to PREPA at this price. Certainly the Cambalache Project is not one of them.

However, if growth is adequate and new capacity must be added within ten years or so, PREPA's avoided cost becomes the life cycle cost of the most expensive unit it would have to install in the absence of the Project. This could be in the range of 8 to 10 cents per kwh. Depending on this latter number,

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

It is beyond the scope of the study to answer 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 PREPA's present forecast of 1.2 percent holds up, "there will be no need for additional generating capacity until the end of the 1990's" (22, p. 26). If the growth of peak demand approaches 2.0 percent, new capacity on the order of 300 mw will be needed early in the next decade (20).

Assuming adequate growth in the demand for electricity, a feasible design for the Project does exist. Many of its parameters have been described and analyzed in the previous sections. This section completes the tasks 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 E-3 excludes inflation, subsidies and taxes. The net cash flows on page five 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:

● <u>Without the benefit of inflation or subsidies</u>, the project generates a positive cash flow from operations beginning in the

fourth year and for every year thereafter. For the Project as a whole, the net cash flow becomes positive in the sixth year, when construction is complete. Average annual cash flows from Table E-3 are summarized in the following table:

TABLE E-1

SUMMARY OF ANNUAL CASH FLOWS

	Operating period		Project
	First	Second	life
	yr. 1-5	yr. 6-25	yr. 1-25
	$000	$000	$000
Operations	(347)	4,227	3,312
Investment	(6,939)	-	(1,388)
Total	(7,286)	4,227	1,924

• Net cash outlays during the first five years of the Project's life total $36.4 million, of which $34.7 million represents the initial investment and $1.7 million, the net loss from operations. During the last 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 expenditures equivalent to 12.2 percent in today's financial markets.* Assuming tax exemption for the project, this return

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*Equals the sum of the inflation-free internal rate of return of 7.74 percent calculated from Table E-1 and investors' current average expections of future inflation of 4.5 percent, from (2).

compares favorably with the 10 percent yield to maturity current-
ly quoted for PREPA bonds with a life of 20 years to redemp-
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.
(JSH) a reputable firm of petroleum engineers and geologists, to
discount future operating profits from proven oil and gas re-
serves. The comparable market rate, calculated from Table E-3, 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
five-years, with other prices held constant. A more modest
assumption of a 2.0 percent annual increase yields a Project rate
of 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), as shown below. The estimates below 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.

TABLE E-2

EMPLOYMENT SUMMARY

Sector	Planted acres	Harvest interval (mo.)	Full-time equivalent jobs Total	Per 1,000 acres	References Section	Tables
Agriculture						
Cane	6,950	12	174	25	B	A-1,A-2,A-6
Grass	5,700	6	233	41	B	A-3,A-4,A-6
Subtotal	12,650		407	31	E	
Crop transportation			37		B,E	A-1 to A-4
(40 ton trucks)					E-1	
Subtotal	12,650		444	34		
Mill & Power Plant			119		C	M-5
Total			563			

Indirect employment is estimated at 634 full time equivalents and total employment at 1,197, using Type II multiplier of 1.52 for agriculture, 1.70 for transportation and 4.33 for the mill and power plant (4, 1978, p.351).

Following are the more important assumptions and conditions used to obtain the above results:

o Except for the choice of "A" sugar and consideration of two TG's instead of one (Alternative B on page 80), there has been no attempt to optimize the Project's conceptual design. In brief, there is room for improvement.

o 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 these changes are structural rather than inflation related, Table E-3 is essentially in constant 1984 prices.

- The price of export energy increases 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 long-run world price, estimated 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-scale and field-plot tests during the AEE/CEER Biomass 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 case.

- All inputs and outputs are valued at market prices, 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. Its cost at the edge of the field is estimated at 20 cents per 1,000 gallons.

- The entire Project is assumed to be undertaken by a single organization which finances the entire operation from its own resources and at its own risk (100 percent equity financing).

- The mill is purchased by the Project on the first day of operations for $3.6 million.

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

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5.2 Methodology

For the purposes of this study, it is convenient to define economics as the art and science which describes, analyzes and evaluates those tradeoffs which can be expressed in monetary terms. Obviously, money is not everything. However, the faculty of judgement breaks down when more than four or five major elements in a problem must be considered simultaneously. Hence, it is useful to have techniques which reduce to a manageable size the number of elements quantifiable in monetary terms, for these tend to be numerous.

Projects such as the one under study are classic illustrations of monetarizable tradeoffs. In this regard, they resemble thermodynamic systems in the sense that a project may be conceived of as a system with boundaries, across which move energy and matter measured in terms of money as well as hours, tons and BTU's. However, unlike the typical thermodynamic systems analyzed in texts, no common <u>physical</u> denominator exists for flows 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 curves. Instead, the pattern of project flows is determined by a large number of external and internal factors which may never be entirely known or predictable.

Nevertheless, most project flows do have money values as a common denominator, for most (if not all) of the physical items moving across the project boundary have a market price or a cost based on these prices. Hence, for every physical movement, there

exists an opposite monetary movement, whether simultaneous or not. And for every pattern of physical flows over time there exists one or more "streams" of money flows. Typically, in the construction and startup periods, the net flow of funds is negative each year, an outflow. In the operating period, the reverse must 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 inputs and payments on account of debt, except perhaps for occasional "bad" years or years of major expansion or replacement. Hence, there 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 inflows of later years compensate for the net out flows of the early years and to what extent? If the answer is negative, the burden of justifying the project may be thrown upon those factors which cannot be monetarized.

At first glance, project evaluation would seem to be a straight forward problem for a microcomputer spreadsheet program, but in fact it is not. Many questions, some of them 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 as "standard costs", and accounting charges, such as amortization and depreciation). Market prices? (These may not always exist or may be distorted by lack of competition, government regulation, etc.).

Or "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 measured? 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 or 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 investment 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. Also for several reasons long-term market rates of return used as reference points usually incorporate some notion of what the long-term rate of inflation will be. This latter rate may be wrong, or inappropriate for the project under study.

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

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

each input and output into the stream of money flows and calculating "future value" of the project, at the end of its life?

Given all possible combinations of the foregoing, it is possible to generate dozens of different streams of money flows (i.e. spreadsheets) for each project, each one of which describes the project from a unique viewpoint. Fortunately, three or four will generally suffice, unless there are many financing alternatives which it is desireable to show separately.

5.3 Economic Cash Flows

The study proposal provides for three separate sets of analyses - economic, financial and a cost-benefit - with one economic analysis to be included in the present Phase I report. This analysis follows and is based on the feasible case summarized in Table 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 boundaries are those of the Project, considered as a single, autonomous, self-sustaining entity. The concern here is, can the Project as a project stand on its own?

As indicated in the title, money flows are cash flows, reflecting the timing of payments and receipts rather than the timing of movements of goods and services across the system boundary, 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, as noted above.

Inflation is omitted from Table E-3 and discussed subsequently for several reasons. There is no rational basis for an

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independent projection of the general rate of inflation more than a few years in the future. Moreover, over the twenty-five years, the inflation rates for individual project inputs and outputs are liable to diverge, and these divergences are liable to become more important to the project than the general rate itself. (For example, energy prices will probably rise faster than most other prices). Projecting these individual rates is more hazardous and uncertain than projecting the general rate. By comparison, although no standard methodology exists, it is easier 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 E-3 are structural, not inflationary, and do not reflect any change in petroleum prices.

The price of electricity and the price of sugar are discussed in detail in "Electricity Demand and Prices" and "Sugar Demand and Prices" following and in the section of "Supplemental Documents" entitled "The World Market for Sweetners."

Table E-3 assumes that the cane mill is bought for $3.6 million (its opportunity cost to the Commonwealth) on the first day of the Project's life, and that the remaining expenditures shown under "A. Initial Investment" are made in the middle of each year. The cane mill operates with its existing boilers and turbogenerators during years one through five, the first operating period. Because of the small number of effective milling

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days in years one, two and three, additional cane should be shipped to Cambalache (or its cane and grass should be shipped elsewhere) 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 Cambalache. During years six through twenty-five, the second operating period, the mill receives steam and electricity from 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 a project is to calculate its internal rate of return (IRR). This is the rate of discount or appreciation which causes the stream of cash flows to sum to zero. Conceptually it is related to the time preferences of human beings.

Most human beings prefer now to later. If they must postpone something which they desire or need, they want to be compensated for it. Hence, if delivery of a good or service lags behind the payment for the same by a significant amount of time, a discount may be called for (for example the prepublication discount on books). Conversely, if payment lags delivery, an extra charge may be in order (for example, the finance charge on

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installment sales). Similarly, charges 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 the future. And most people require some (although not very much) monetary incentive to save a little and a strong incentive to save a lot.

The situation as regards the production of goods and services for sale or exchange is more complex but not essentially different from the above, in most cases. Almost every business, regardless of size or economic system, has a continuous need for the 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 risks are greater in number, magnitude and uncertainty than short term ones. So most people and organizations including prudent bankers, lessors and suppliers are adverse to indefinite commitments to others and reluctant to enter into long-term ones, regardless of promises, fixed terms for payment and guarantees. (Governments, insurance companies, pension funds and venture capitalists are the principal exception.) Hence someone else must commit money to the enterprise, but on an indefinite basis, subordinate to the claims of others and subject to total loss. This is called equity financing, to distinguish it from the credit financing provided on specific terms by bankers or suppliers. However, even equity financing is made in the _hope_ of

earning a return on, and securing the recovery of, the amount invested. And, like any long-term commitment in a world of scarcity, equity financing involves an opportunity cost to the provider. Indeed, many hybrid types of financing exist today. 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 tradeoff between the present and the future, this time preference of human beings is a natural phenomenon. It is not the invention of usurers on the exclusive property of some economic system. 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 expectations about inflation, any set of cash flows has an equivalence at each point in time which depends basically on the rate (r) at which the analyst appreciates the past or discounts the future, that is, on his (or her) rate of time preference. For example, to determine the present value of stream of flows as of the first day of a project life of (t) periods, the cash flow corresponding to each periods is divided by $(1+r)^t$ and the discounted flows are summed. Conversely, calculating the future value of a stream on the last day of the project requires each period flow to be appreciated, that is, to be multiplied by $(1+r)^t$. The stream may be also evaluated at some intermediate point, say the first day of operations. In this case, prior periods are appreciated, and

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 realistic. 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 time-adjusted flows equal to zero. Moreover, the net cash flows can be invested at rate in existing financial markets, as assumed 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 have 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 test 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

enterprise. At the same time, wide variations in rates of return on investment (12) and rates of technological change across industries have developed. In some electronics industries, a product is obsolete in less than three years. Unit costs 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 appropriate industries are the energy industries, because the Project under study is primarily designed to replace oil in the expansion of PREPA's electric generating system. In 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-3 uses constant prices, and the two structural price changes practically cancel 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.

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*The 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 compound over the Project's 25 year life - 1.4% in the first ten years and zero in the last fifteen.

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 time 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 from the market rate of interest for a relatively riskless security, such as 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 remaining 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 problems 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 implicitly from an internally consistent forecast of GNP, interest rates and stock prices (2).

Still another approach is to take an evaluation of an appropriate energy-industry cash flow such as that of JSH which incorporates an inflation rate, apply the inflation rate to the energy product prices in Table E-3 and see how the resulting IRR compares with the reference discount rate.

JHS assumes that the individual company's price per barrel of crude oil will remain constant during 1985-88, then increase to $75 per barrel by the year 2000 and remain constant there-

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after. Other prices and costs are constant at all times. Taking a weighted average of the U.S. Department of Energy's "actual domestic average wellhead price" and its "average f.o.b. cost of crude oil imports" for 1984 (14, p. 89), which is $26.81, JSH's assumption implies an annual rate of inflation in energy prices of 9 percent during the period 1989-2000. This is equivalent to a constant rate of 4.6 percent for twenty-five years starting in 1986. Applying this rate of inflation to electricity prices for years four through 14 in Table E-3 gives an IRR of 18 percent for the life of the project, which compares vary favorably with JSH's own discount rate of 15 percent, assuming both are subject to income taxes at the same rate. This confirms the economic feasibility of the project under the assumption of PREPA expansion.

The comparison is even more favorable than it looks because producing oil from existing wells is more risky than producing energy and other products from biomass. Both activities, of course, use a mix of proven technologies or new technologies with proven components. However, oil production is subject to a variety of royalties and production taxes, in addition to income taxes. The former may be arbitrarily varied by governments and cannot always be passed onto consumers. Also because of technical problems in estimating oil-well decline curves (15), the future output of a 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.

5.5 Target Rate of Return

In the IRR calculation, the rate of return on investment is the plug figure whose value is allowed to vary so that the cash flows will sum to zero, i.e. so the money flows will "balance". In 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 E-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, oil-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 investment charges. Taking non-electric revenues as given, the levelized annual required revenue from the sales of electricity is $10.4 million, equivalent to 10.09 cents per export kwh as shown in Table E-5. This figure is higher than the year ten price of 9.8 cents per kwh of Table E-3 for the reasons explained in footnote to Table E-5.

5.6 Product Prices and Project Costs

In today's world, growers and processors of agricultural raw materials and some food crops can no longer afford to think of themselves as mere producers of a bulk commodity or focus stubbornly on a single end use. To do so is to condemn themselves to the perpetual economic torture of wide price fluctuations, low average prices, overproduction, dumping and even the invasion of their markets by new products and/or new competitors. In brief, for more and more growers and processors, multiproduct output is the key to biomass economics.

Moreover, it is typical of such operations that, among 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-percentage-of-cost pricing so common in business will lead to optimal prices only by rare coincidence. Instead, the seller of the final products must optimize their collective contribution to joint costs, both fixed and variable; that is, optimize the difference between total revenues and total product specific costs. In other words, the cane grower or processor must think of it as if it were a refinery or a slaughterhouse, with a valuable and verstile raw material to convert into a "slate" of products whose number, identity and characteristics will vary from time to time as changes in market conditions and technology dictate (16,17).

A case at hand is the project under study. Table E-4 shows an estimate of the percentage distribution of economic costs for the Project in year eight, when maximum grass production is reached. Note that roughly 50 percent of total economic costs are variable and of these about 62 percent (or 31 percent of the total) are joint.

5.7 Electricity Demand and Prices

As elsewhere in the world, the demand for electricity in Puerto Rico is a derived demand. Electric energy is not desired for itself but rather is an input to the production, distribution or 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 activity. 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, a severe and sometimes disastrous effect on businesses, such as hotels and continous-process operations, whose electric 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 amount of energy consumed. The income elasticity is only 0.02, so that a 10 percent change in income translates into a 0.2 percent parallel change in energy use.

Tragically, for almost a decade, the Puerto Rican economy has been growing primarily on the basis of transfer payments, especially those unrelated to the production of goods and services in any consumption period. This is shown in Table E-7. After a brief spurt following the 1973 oil crisis and the 1974-75 recession, the productive sectors of our economy 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" for purchased, base-load power is, at the moment, the incremental operating cost of its oil-fired base-load units which is esti-mated at 5.4 cents per kwh for the purposes of this study (19). At this price, almost no alternative to petroleum is attractive.

However, the present situation of Puerto Rico is dynamic, not static. One way or another, 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. Small island economies, 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, regardless of their economic or political system. It will take ten years, with no assurance of success, to reorient

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 volume of potential investment funds as Section 936*. In this case, obviously, the excess of generating capacity will increase rather than decrease.

If Section 936 is preserved but business and government go on acting 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 few 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 will grow on the basis of productive activity.

Economic growth, of course, means growth in electricity consumption, albeit at a slower rate. Hence, if Section 936 is retained, an outcome such as shown in Table E-9 is possible. Although not shown directly, the implied growth in total output is about 4 percent per year compounded, before inflation. The indicated growth in electricity consumption is about half of that, 2.2 percent per year, as compared with an average annual decrease of 2.6 percent for last five fiscal years (Table E-6, footnote one). Coincidentally, this is very close to the 2.0 percent shown in PREPA's March 1984 forecast (20, Table 8). The

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*A member of the study team worked on the three proposals to the U.S. Congress to save Section 931 and later replace it by Section 936.

corresponding peak-load forecast shows an annual growth at a rate of 1.7 percent. (20, Table 8 and 21, Cuadro 4). This latter rate requires addition of 300 mw of coal-fired, base-load capacity in fiscal year 1993-94 and again in 1994-95 (21, Cuadro 1). Also, 188 MW of existing oil-fired capacity is to be retired through June 1994, for a net gain of 112 mw. Varying the loss-of-load probability does not reduce the requirement for new base-load capacity in 1993-94 (21, Cuadro 6).

Given adequate growth in demand, PREPA's avoided cost will shift to the life-cycle cost of a new generating unit by 1994. An illustrative estimate of this cost for a coal plant is shown in Table E-10, based on PREPA's 1982 study (23) and other sources. Although the estimate appears low, the figure of 6.6 cents certainly makes alternatives unattractive, if only unit life-cycle cost is considered.

However, per Table E-10, the initial investment required for one unit is estimated at $600.7 million or $2,002 per gross kw, in 1984 prices. The total investment for a three-unit, 900 mw generating station is estimated at $1.6 billion or $1,782 per gross kw, with an annual investment charge of about $223 million. By comparison, the gross value of PREPA's total electric plant in service or under construction on June 30, 1984 was only $2.3 billion (historial cost). Moreover, after providing for current expenses its total payments to various funds in fiscal year 1983-84 as a result of contractual obligations were only $191 million (24). Thus a move to coal, however attractive in terms of life cycle cost, could strain the organization's debt

service capacity, especially if electricity consumption grew more slowly than expected.

Table E-10 reflects the foregoing in part by using a capital cost of 13 percent per year, instead of the 10 percent currently accepted by the Authority's bondholders. Still, the magnitude of the required investment is so great as to possibly be prohibitive. Financing alternatives to bonds raise difficult financial or 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 E-3, is only $969 per gross kw.

It is beyond the scope of this study to evaluate these alternatives other than the Project at hand. Nevertheless, it is safe 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 E-11. 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 times involved in most alternative energy projects, especially coal plants, it seems both fair and wise to phase in gradually the change in avoided cost. The critical date in this regard is not the date on which the new unit should enter service, but the last date on which a decision to construct (or not to construct) can be made. In the case of a coal plant, this date may be only a few years away. Therefore, the price of electricity in Table E-3 increases from 5.4 cents per kwh in the first Project year to 9.8 cents in the tenth.

5.8 Sugar Demand and Prices

World consumption of sweetners is more than 122 million short tons per year, of which 103 million shorts or less than 84 percent is for cane and beet sugar, with a sucrose content of 96 percent in the raw forms. About 65 million tons or a little over half of the world total is derived from cane. Corn sweetners 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 agreements, so only 20 percent is traded on world markets under anything approaching competitive conditions. Demand tends to follow population growth and be relatively insensitive to changes in prices and incomes. From the producer's point of view, raw sugar is a bulk commodity with no meaningful distinctions between cargoes meeting trade standards for quality. All cane growers face lead times 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 countries must aim for maximum sales, almost regardless of price, because of the need for foreign exchange, the need to maintain employment, lack of good alternative uses for cane land and/or inability to finance a switchover. Overproduction is more common than the opposite. World inventories currently stand at almost twice the desired level, and it will take at least five years to work off the excess.

As a result, the world market for sugar is a residual market, in which most product moves with export subsidies and/or is sold at "dump" prices, frequently at a loss. 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 raw 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 for 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 or 13 percent of world sweetner consumption, with over half supplied by sucrose (including 6 million tons or 38 percent by cane sugar). Forty percent is supplied by corn syrups and about seven percent by other sweetners. In the U.S, and other industrialized countries high-fructose corn syrups (HFCS) are increasingly 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 semi-closed. An elaborate system of loans, subsidies and trade restrictions fairly well limits sugar imports to the U.S. production deficiency and maintains the domestic price in the neighborhood of 21 cents per pound. The latter price is, of course, 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

that Puerto Rico's traditional industry will ever be competitive again. Nevertheless, as long as the U.S. price remains well above the world price, and there are other products to help pay manufacturing 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.o.b the mill, a pound of sucrose in sugar is worth over four times its value as just another fermentable solid in A molasses, at 49 cents per gallon 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 imported.

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 from 22 to 11 cents per pound in ten years. For a more detailed comprehensive or overview of the Puerto Rican, U.S. and world sweetner markets, see "World Sweetner Markets" in the "Supplemental Documents" of this Report.

5.9 Molasses Demand and Prices

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 system. As it comes from the centrifuges, this product is too viscous for pumping or consumption. Depending on end use, it is diluted with water to trade standards. For animal feed, apparent soluble solids should be at least 79.5 percent (measured degrees Brix) and total sugars (sucrose and others) at least 46 percent,

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 discrepancy 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 yeast, distilled spirits and pharmaceuticals. To complicate matters further, blackstrap competes in some uses with molasses derived from sugar beets, citrus fruits or other raw materials; and statistics for the different types of molasses may be commingled, or presented by weight or volume without giving equivalencies. For example, molasses produced in Europe is derived from 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 animal feed markets traditionally supplied by blackstrap.

World production of all kinds of molasses for industrial purposes for the crop year 1983-84 exceeded 33.3 million metric tons, with Brazil, India, the Russian block and the European Economic Community accounting for 48 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 more molasses is retained in the country of origin for animal feed and ethanol.

For the U.S. mainland consumption of all kinds of molasses 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.o.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 1982-83 imports.

As a residual byproduct of a bulk commodity which is in world surplus, both long-term and short-term, blackstrap molasses also exhibits marked price fluctuations. From a high of 69 cents per gallon f.o.b. New Orleans in February of 1981, it fell to a

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*Source: Puerto Rico Planning Board

low of 6 cents in November of 1982; it then recovered to 41 cents in October of 1983 where it remained until June 1984, dropping gradually to 29 cents where it remained until June 1985. For the purposes of this Report, the A molasses price is based on a blackstrap price of 30 cents per gallon f.o.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 a more desirable distillation feedstock than blackstrap, no insuperable technical difficulties are anticipated in convincing local 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 a 100,000 pound per hour boiler. Thus, a minimum supply of distillation slops, once considered to be only an obnoxious waste, is required at all times.

The main problems foreseen in marketing project molasses are assuring security of the A molasses supply through long-term contracts and arriving at a mutually acceptable, flexible price formula. These matters will be studied further in Phase II.

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 variables and between these and major assumptions will be undertaken in Phases II and III of this study. However, some 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. It 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 enough revenue from sales to cover operating expenditures.

• 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 increase to the point where the Phase I version of the project is economically feasible.

• A ten percent increase in the average cane yield per acre will increase the delivered cost of cane about six percent and

the levelized annual economic cost of the project, about two percent. However, electricity exports, sugar revenues and molasses revenues should also increase, so the required price of electricity should decline about 10 percent, to 8.9 cents per kwh. That is, a change in cane yields should produce an opposite change in the required price of electricity of roughly the same magnitude.

● A ten percent increase in the average grass 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 grass yields has much less effect than increasing cane yields, so long as grass is used only in the off season.

● A ten percent increase in the target rate of return on investment, from 7.0 percent to 7.7 percent, will increase the required price of electricity by only 1.5 percent. A 10 percent increase in construction costs will increase the annual economic 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.

● The project is likely to obtain less benefit from inflation than a project with the same initial investment and revenues 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 inflation, so the price of electricity must increase faster for the two projects to show the same IRR in a given period. For example, if the general rate is ten percent and the rate for sugar and molasses is five percent, the rate for electricity must be 13.5 percent for project revenues to grow at the general rate. However, this is only liable to be a problem at high rates of inflation 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 changes in technology on markets, such as changes in the type and volume of fuels available, a molasses shortage in world markets, commercialization of sucrose chemicals, commercialization 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 a turbogenerator fuel. The project boiler can burn a wide variety of biomass fuels 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 modest cost. With supplemental fuels during the milling seasons, generating capacity could be expanded. A distillation unit, using

50 psig steam for example, could easily be added to the complex.

5.11 Work to be Done in Phases II and III

As indicated in previous sections, the main thrust of these phases will be optimization and completion of the conceptual design in terms of all relevant criteria. This includes site analysis, the preparation of all preliminary drawings, 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 include:

● Final design

● Preparation of documents and specifications required for contracting and procurement.

● Contracting, procurement 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 Phases II and III include the following:

● Determination of economic life, operating cost and maintenance cost of equipment, machinery and structures to be installed in the project.

● Evaluation of the conceptual design from the economic, financial and cost benefit points of view.

● Evaluation of alternatives for the financing management, organization and ownership of project components.

TABLE E-3

SCHEDULE OF PROJECT ACTIVITIES AND ECONOMIC CASH FLOWS BY HARVEST YEAR

(1984 PRICES)

Description	Total Amount ($000)	First period					Second period					Ave.11-25
		1	2	3	4	5	6	7	8	9	10	
A. Initial investment												
1. As put in place												
Drainage	860	290	290	280	-	-						
Value of Mill	3,600	3,600	-	-	-	-						
Mill improvements	1,944	1,944	-	-	-	-						
Power Plant												
Structures, etc.	1,765	-	1,250	515	-	-						
Boiler	6,494	-	-	1,300	2,600	2,594						
Boiler related	6,202	-	-	-	3,100	3,102						
Turbogenerator,etc.	7,636	-	-	1,550	3,800	2,286						
TG related	1,992	-	-	-	950	1,042						
Painting	37	-	-	-	-	37						
Substation equipment	507	-	-	100	250	157						
Construction facilities	125	125	-	-	-	-						
Subtotal (Power)	24,758	125	1,250	3,465	10,700	9,218						
Consultants	200	100	25	25	25	25						
Design & general	1,050	300	300	250	100	100						
Freight & related	937	10	10	200	600	117						
Subtotal (Power)	26,945	535	1,585	3,940	11,425	9,460						

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Description	Total Amount	First period					Second period					Ave. 11-25
		1	2	3	4	5	6	7	8	9	10	
Contingencies (5%)	1,347	25	80	200	570	472						
Total (Power)	28,292	560	1,665	4,140	11,995	9,932						
Total (All)	34,696	6,394	1,955	4,420	11,995	9,932						

2. Cumulative average

Description	Total Amount	1	2	3	4	5	6	7	8	9	10	Ave. 11-25
Total (All)	34,696	4,997	9,196	12,413	20,655	31,619	34,696	*	*	*	*	*

B. Agricultural operations

1. Harvest areas (acres)

Description	Total Amount	1	2	3	4	5	6	7	8	9	10	Ave. 11-25
Cycle One (PR 980)	–	1,300	1,300									
" Two "		–	2,300	2,300								
" Three "		–	–	1,300	1,300							
Subtotal (PR 980)	–	1,300	3,600	4,900	3,600	1,300						
Cycle Four (US 67-22-2)				1,300	1,300	1,300						
" Five "			–		2,300	2,300	2,300					
" Six "			–	–		2,300	2,300					
" Seven "			–	–		2,300	2,300					
Subsequent cycles "			–	–	–	2,300	2,300	4,600	6,900	*	*	*
Subtotal (US 67-22-2)				1,300	3,600	5,900	6,900	6,900	*	*	*	*
Subtotal (cane)		1,300	3,600	6,200	7,200	6,900	6,900	6,900	*	*	*	*
Subtotal (grass)						1,900	3,800	5,700	*	*	*	*
Total (all crops)		1,300	3,600	6,200	7,200	8,800	10,700	12,600	*	*	*	*

*Signifies that number to left on same line is repeated.

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Page 3 - Continued Table E-3

Description	Total Amount	First period					Second period					
		1	2	3	4	5	6	7	8	9	10	Ave.11-25
2. Harvest weights (short tons)												
Whole cane	85,800	237,600	433,900	543,600	587,300	590,400	*	*	*	*	*	*
Fallen trash	7,700	21,200	31,100	34,900	34,900	35,100	*	*	*	*	*	*
Grass						112,100	224,200	336,300	*	*	*	*
Total	93,500	258,800	465,000	578,500	622,200	737,600	849,700	961,800	*			
3. Production costs ($000)												
Cane & trash	1,690	4,255	6,970	7,998	8,151	7,939	*	*				
Grass						2,903	4,897	7,409				
Subtotal	1,690	4,255	6,970	7,998	8,151	10,842	12,836	15,348	*			
Use of working capital	118	298	488	560	571	759	899	1,074	*			
Training and extension	35	78	93	68	48	91	109	122	84			
Total	1,843	4,631	7,551	8,626	8,770	11,692	13,844	16,544	16,506	*		
4. Unit production costs ($/short ton)												
Whole cane	19.70	17.91	16.06	14.71	13.88	13.45	*	*				
Grass						25.90	22.84	22.03				
Total	19.71	17.89	16.24	14.91	14.10	15.85	16.29	17.20	17.17	*		
C. Transportation cost ($000)												
Total	281	776	1,395	1,736	1,876	2,212	2,549	2,885	*			

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Description	Total	First period						Second period				
	Amount	1	2	3	4	5	6	7	8	9	10	Ave. 11-25
D. Delivered cost of crops												
1. Total ($000)	2,124	5,407	8,946	10,362	10,637	13,904	16,393	19,429	19,391	*	*	*
2. Unit ($/short ton)												
Whole cane	22.71	20.91	19.06	17.71	16.88	16.45	*	24.84	*	*	*	*
Grass						28.70	*	*	25.03	*	*	*
Total	22.71	20.89	19.24	17.91	17.10	18.85	19.29	20.20	20.17	*	*	*
E. Industrial operations												
1. Effective milling days	24	66	121	151	161	164	*	*	*	*	*	*
2. Effective generating days	24	66	121	151	161	212	261	309	*	*	*	*
3. Mill O. and m. expenses ($000)	1,591	2,169	2,916	3,334	3,500	2,790	*	*	*	*	*	*
4. Power Plant O.and m. expenses ($000)						802	1,008	1,214	*	*	*	*
Total ($000)	1,591	2,169	2,916	3,334	3,500	3,592	3,798	4,004	*	*	*	*
F. Revenue estimate (for calculation of net cash flows)												
1. Output												
Electricity exports (000 KWH)												
Cane & trash	503	1,390	2,412	2,955	3,146	77,933	*	*	*	*	*	*
Grass						29,232	58,464	87,696	*	*	*	*
Total	503	1,390	2,412	2,955	3,146	107,165	136,397	165,629	*	*	*	*
"A" sugar (short tons)	4,578	12,678	23,152	29,005	31,338	31,503	*	*	*	*	*	*
"A" molasses (000 gallons)	1,255	3,477	6,349	7,954	8,593	8,639	*	*	*	*	*	*

	Total	First period					Second period					
Description	Amount	1	2	3	4	5	6	7	8	9	10	Ave. 11-25
2. Prices												
Electricity (cents/KWH)		5.3	5.7	6.1	6.5	7.0	7.5	8.0	8.5	9.2	9.8	*
"A" Sugar (cents/lb)		22.0	20.4	18.9	17.5	16.2	15.0	13.9	12.8	11.9	11.0	*
"A" Molasses (cents/gallons)		49.0	*									*
3. Revenues ($000)												
Electricity		27	79	147	192	220	8,037	10,912	14,078	15,238	16,232	*
"A" sugar		2,014	5,173	8,751	10,152	10,154	9,451	8,758	8,065	7,498	6,931	*
"A" molasses		615	1,704	3,111	3,897	4,211	4,233	*	*	*	*	*
Less handling and sales expenses		(170)	(447)	(771)	(913)	(934)	(889)	(844)	(799)	(763)	(726)	*
Total		2,486	6,509	11,238	13,328	13,651	20,832	23,059	25,577	26,206	26,670	*
C. Net cash flows ($000)												
Operations		(1,111)	(769)	(136)	192	85	4,095	3,767	3,218	3,885	4,349	*
Initial investment	(34,696)	(6,394)	(1,955)	(4,420)	(11,995)	(9,932)						
Net		(7,505)	(2,724)	(4,556)	(11,803)	(9,847)	4,095	3,767	3,218	3,885	4,349	*

Notes to Table E-3

A. Initial investment

   1. As put in place

   Drainage   Equals $68 per planted acre.

   Value of mill   Total column per "valuation of the Camba-
                               che Mill in Supplementary Documents."

   Mill improvements   Total column per Table M-6, Section C.

   Power Plant   Total column per Table P-2. Section D.

   2. Cumulative average   Assumes mill bought on first day of Proj-
                               ect life, other investment expenditures
                               made at mid year of year indicated.

B. Agricultural operations

   1. Harvest areas   Based on Table A-6, Section 2.0

   2. Harvest weight   Base on yields indicated in Section 2.0

   3. Production costs   Based on above and Tables A-1 through A-6,
                               Section B. Use of working capital equals
                               subtotal x 70% x 10%. Training and exten-
                               sion expenditures assume 75 planted acres
                               per farmer, $2,000 per new farmer per year,
                               $500 per farmer with one year or more of
                               energy crop experience.

C. Transportation   Equals harvest weight x $3.00 per short
                               ton.

E. Industrial operations

   1,2. Effective days   Per Section D.

   3. Mill o and m expense   Per Table M-9, Section C.

   4. Power Plant o and m   Equals gross generation per tables P-4
      expense   P-5, Section D, x 0.67 cents per kwh.

F. Revenue estimate

   1. Output - electricity   Per tables P-4 and P-5, Section D.
             - A sugar   Calculated from table M-5, Section C.
                               Assumes cane juice contains 90% of soluble
                               solids in cane, 93% of these are ferment-
                               able, 85% of latter are sucrose and 60% of
                               sucrose in juice is extracted. Raw sugar 96%
                               pure.

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2. Prices

See Section E.

3. Revenues

Handling and sales expense equals 6.5% x revenues from sales of sugar and molasses.

G. Net cash flow

Exclude use of working capital, inflation and taxes to facilitate calculation of in ternal rates of return, present values, etc Under varying assumptions about cost of ca pital inflation and taxes.

TABLE E-4

LEVELIZED ANNUAL ECONOMIC COST OF PROJECT

	$000[1]	%	Unit Cost[2]
Agricultural Operations			
Cane and trash[3]	7,111	34.5	$13.96 per short ton of whole cane
Grass[3]	4,410	21.4	$22.14 per short ton of grass
Miscellaneous[4]	887	4.3	
Subtotal	12,408	60.2	
Transportation	2,220	10.8	$3.00 per short ton of biomass
Cum. subtotal	14,628	71.0	
Mill and Power Plant	3,487	16.9	
Cum. subtotal	18,115	87.9	
Investment charges[5]	2,500	12.1	
Total	20,615	100.0	

Notes

[1] Calculated from Table E-3. The appropriate annual flow of expenditures is first discounted to Project year one at an average annual rate of seven percent compounded. The resulting present values is then multipled by the corresponding annual capital recovery factor of 8.58 percent, to obtain the levelized annual economic cost.

[2] To obtain the levelized unit cost, the present value of the expenditures flow is divided by the "present value" of the appropriate flow of physical units, also discounted at seven percent.

[3] Includes rental of land (at $50 per acre) and machinery.

[4] Comprised of charge for use of working capital (10 percent per year on 70 percent pf production expenditures) and extension expense.

[5] 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 is calculated as follows: Only interest is paid during the first five years. During the last 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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LEVELIZED ANNUAL REVENUE REQUIRED

	$000[1]	%	Unit price
Revenues from sales			
Electricity	10,409	50.5	10.09 cents per KWH
Sugar	7,265	35.2	13.34 cents per lb.
A molasses	3,651	17.7	49.00 cents per gallon
Handling and sales expense[3]	(710)	(3.4)	
Net revenues	20,615	100.0	

Notes

[1] The total is identical with the in Table E-4 sugar and molasses revenues are determined as are levelized annual expenditures in Table E-4 Electric revenues are determined by difference.

[2] Determined as are unit costs in Table E-4. The unit price of export energy is slighly higher than the highest price shown in Table E-3 because, in Table E-5, working capital is changed for separately at 10 percent per year and amortization of the initial investment takes place in 20 years instead of 25.

[3] Equals 6.5 percent of revenues from sales of sugar and A molasses.

TABLE E-6

DISTRIBUTION OF ECONOMIC COSTS

PROJECT YEAR EIGHT

| | | Percent of item total | | | Line Total |
| | Fixed | | Variable Costs | | as % of |
Item	Costs %	Joint %	Specific %	Total %	Project total %
Agriculture[1,2]					
Cane	42	58	–	100	31
Grass	57	–	43	100	28
Subtotal	49	30	21	100	59
Transportation	–	65	35	100	10
Subtotal	42	35	23	100	69
Cane Mill O.& M	36	64	–	100	10
Power Plant O.& M	70	14	16	100	4
Handling					
and sales	–	–	100	100	3
Investment					
charges[3]	100	–	–	100	14
Total	50	31	19	100	100

[1]Rent of land and interest on working capital charges included in "Agriculture".

[2]Training and extension included in "Agriculture".

[3]Interest and amortization of initital investment.

Source: Table E-3

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ROLE OF FEDERAL TRANSFER PAYMENTS TO INDIVIDUALS
IN PUERTO RICO'S ECONOMY
(CURRENT PRICES)

	Fiscal year		Ave. annual
	1983-84	1973-74	change
	$ millions	$ millions	%
Transfers to individuals			
Related to production of goods and services in prior years[1]	1,637	550	11.5
Partially related[2]	186	36	17.8
Unrelated[3]	1,267	21	50.7
Not classified	(16)	–	
Subtotal	3,074	607	17.6
Less employee contributions			
50% Social Security	(397)	(167)	9.0
Civil Service retirement	(14)	(6)	8.8
Health & life insurance	(12)	(4)	11.6
Subtotal	(423)	(177)	9.1
Net	2,651	430	19.9
Personnal income			
Total[4]	13,386	6,002	8.4
Less non-Federal transfers	(991)	(406)	9.3
Net	12,395	5,596	8.3
Ratio			
Net Federal transfers to net personal income	21.4%	7.7	11

Continued Table E-7

<u>Notes</u>

1. E.g. Social Security, pensions

2. Medicaid

3. All other

4. After deduction of contributions to all forms of social insurance but before income tax.

<u>Source</u>

Estimates calculated from: Anon. Informe Económico al Gobernador 1983-84" (Tomo 1), Junta de Planificación de Puerto Rico, San Juan, 22 de enero de 1985, Apéndice tablas 8 y 19.

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[1] - number (000)			(244)	
Population -				
number (000)	3,270	2,878	392	1.3%
Working-age				
(W/A) population[2]				
number (000)	2,261	1,194	347	1.7%
% pop.	69.1%	66.5%		
Labor force				
number (000)	952	847	105	1.2%
% W/A population[4]	42.1%	44.3%	(2.2)[3]	
Employed				
number (000)	742	744	(2)	-
% W/A population	32.8%	38.9%	(6.1)[3]	
Unemployed				
number (000)	209	103	106	7.3%
% W/A population	9.2	5.4	3.8[3]	
% Labor force[5]	22.0	12.2	9.8[3]	

Notes
[1] By differences
[2] Fourteen years or older 1974; 16 years, 1984
[3] Percentage points
[4] Participation rate
[5] Unemployment rate

Source: Anon, "Informe Económico al Gobernador 1983-84",
(Tomo 1), Junta de Planificación de Puerto Rico,
22 de enero de 1985, Apéndice, tablas 22 y 23.

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 - KW[1]	1,159	1,185	(26)	(0.2)
Ave. generation - KW[2]	1,402	1,407	(5)	-
Peak load - KW[3]	1,875	1,823	52	0.3
Dependable capacity -KW	4,207	3,080	1,127	3.2
Peak less installed	2,332	1,257	1,075	6.4
KW - % cap.	55.4%	40.8%	14.6[4]	1.5[4]

Notes

		All-time high		Ave. annual
	1983-84	Value	Year	change
				%
[1] Ave. sales - KW	1,159	1,321	1978-79	(2.6)
[2] Ave. generation-KW	1,402	1,562	1977-78	(1.8)
[3] Peak load - KW	1,875	2,058	1978-79	(1.8)
[4] Percentage points				

Source: Puerto Rico Water Resources Authority

TABLE E-11

A POSSIBLE FUTURE FOR PUERTO RICO

	Fiscal year		Ave. annual	
	1993-94[1]	1983-84[2]	Change	change
	(000)	(000)	(000)	
Population-number (000)	3,612	3,270	342	1.0%
Working - age (W/A) population				
- number (000)	2,589	2,261	328	1.4%
- % population	71.7%	69.1%	2.6[3]	0.3[3]
Labor force				
- number (000)	1,142	952	190	
- % W/A population[4]	44.1%	42.1%	2.0[3]	
Employment				
- number (000)	1,005	742	263	3.1
- % W/A population	38.8%	32.8%	6.0[3]	
Unemployment				
- number (000)	137	209	(72)	
- % W/A population	5.3%	9.2%	(3.9)[3]	
- % Labor force[5]	12.0%	22.0%	(10.0)[3]	
Manufacturing Employment[6]				
- number (000)	208	142	66	3.9%
- % employment	20.7%	19.1%	1.6[3]	
Production - index	162	100	62[3]	4.9%
Electricity consumption (million kwh)				
Manufacturing	4,574	3,188	1,386	3.7
Residential	3,978	3,474	504	1.4
Other	4,030	3,493	537	1.4
Total	12,582	10,155	2,427	2.2

Continued - Table E-11

Notes

[1]Estimated from Anon. "La Población de Puerto Rico para el Año 2000", Junta de Planificación de Puerto Rico, San Juan, Octubre de 1984, Tabla 1, and following assumptions or targets.

- The labor force participation rate increases two percentage points in ten years.

- The unemployment rate decreases ten percentage points in ten years.

- Twenty-five percent of the net new jobs created are in the manufacturing sector.

- Labor 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 half the rate of non-manufacturing employment.

[3]Percentage points

[4]The labor-force participation rate.

[5]The unemployment rate.

[6]Per the household survey.

[2]From Anon. "Informe Económico al Gobernador 1983-84" (Tomo I), Junta de Planificación de Puerto Rico, San Juan, 22 de enero de 1985, Apéndice tablas 23 y 24, and anon. "Monthly Report to the Governing Board - June 1984", October 1, 1984, San Juan, p. 30

TABLE E-12

LIFE CYCLE COST OF NEW COAL-FIRED
ELECTRIC GENERATING STATION IN PUERTO RICO
(1984 PRICES)

		$ million	$/KWH
A.	Initial investment		
	Coal-pier	83.4	93
	Unit No. 1 (300 MW w/scrubber)	517.3	1,724
	" No. 2 (" " ")	504.7	1,682
	" No. 3 (" " ")	498.5	1,662
	Total	1,603.9	1,782

Capital recovery factor (%) (13%/yr, 240 months)	x 13.908	
Annual investment charge ($ million)	223.1	
Annual net generation (MWH) (3 x 2,038.9 MWH)	- 6,116.7	
Unit cost (cents/KWH)	3,647	

		Unit	Amount
B.	Fuel expense		
	Delivered cost of coal	$/short ton	56.00
	Efficiency	KW/short ton	- 2,400
	Unit cost	cents/KWH	2.333

C.	Summary		
	Investment charge	cents/KWH	3.647
	Fuel expense	"	2.333
	Operating and maintenance expense	"	0.592
	Total		6.572

Sources: Estimated from Llavina, Jr. R. "A Status Report on PREPA's Coal Project," Puerto Rico Electric Power Authority, March 1982, 20 pp. and other proposals for Caribbean locations.

TABLE E-13

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	3.539
Fuel expense[1]	"	5.662
Operating and maintenance expense	"	0.592
Total		9.793

Note

[1] Assumes 560 KWH per barrel at $28.00 per barrel of No. 6 fuel oil plus 13.2% "security premium" to reflect maximum excess over spot prices which the Arabian-American Oil Company's private-sector partners appear willing to pay the Government of Saudi Arabia, without strong protest.

Sources: Estimated from Llavina, Jr. R. "A Status Report on PREPA's Coal Project," Puerto Rico Electric Power Authority, March 1982, 20 pp. and other proposals for Caribbean locations.

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6.0 CONCLUSIONS AND RECOMMENDATIONS

Several important conclusions can be made about the different areas reported on earlier.

The agriculture component is feasible because new types of energy grass and cane have been developed for use in Puerto Rico and because the agriculture problem is one of reorienting the growers and workers rather than of introducing new technology. The important question, though, is can enough land be given over to this project to insure its success? About 7,000 more acres must be found in Phase II before the Project can continue.

Although the mill itself has fallen into disrepair, a detailed 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 from the Sugar Corporation before additional improvements 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 enough steam for the milling process and energy for export. Two alternatives 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 all important respects, provided three conditions are met:

- The basic 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 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, it is recommended that Phases II and III of the study be undertaken immediately, for the following reasons:

- 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 industry in Puerto Rico is no longer viable.

- Creation of a new cane industry in Puerto Rico is a major option for agricultural development and petroleum import substitution which cannot be ignored.

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

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