DEMAND AND PRICES - MOLASSES DEMAND AND PRICES ACTIVITY ANALYSIS

6.0 CONCLUSIONS AND RECOMMENDATIONS

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 workforce.

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 1961 cane harvest due to 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 varieties 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.

The implementation of the project is primarily a management problem, not a technological one. This report is the final report for Phase I of the project. It addresses the agricultural needs by describing the new varieties and projecting tonnage yields. It also lists the repairs and improvements that will need 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 which are both described in detail in the chapter on the power plant.

An in-depth economic analysis provides the necessary background to understand the electric power situation on the island and presents scenarios in which the Cambalache project will be economically viable. In terms of agriculture, the sugar cane crop must be replaced with new types of energy cane and grass that can be harvested year-round. Area farmers will need to be educated, most likely through the extension services program, about new methods of land preparation, planting, cultivation, harvesting, and crop rotation.

The available land has dwindled from 15,400 acres in 1972 to 9,200 acres in 1980. Sugar cane has been replaced by dairy farming, pineapple growing, and an experimental rice project as the primary 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, with proper irrigation and drainage, the yield of energy cane that can be produced using variety US 67-22-2 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, which 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 have yet to be defined.

The project covers about 13,920 planted acres, or 25,310 acres in farmland, allowing for 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 problems such 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 land availability 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 produce 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 improvements 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 downtime 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 likely $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 turbo generator for the generation of electricity for PREPA and the mill. During the cane milling season, intermediate

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 crystallization of sugar, and other purposes. The boiler will be capable of producing 215,000 pounds per hour of steam at 850 pounds per square inch with a calorific value of 1,494 BTU per pound of steam. The turbo generator is of the double-extracting/condensing type with a planned output of 22,000 xu per hour when extracting for the mill. With 62 short tons of 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. By its sixth year, the project will generate the equivalent of 563 direct full-time jobs and 634 indirect jobs for a total employment of 1,197. The entire project must be undertaken by a single organization which finances the entire operation from its own resources at its own risk. The report notes that PREPA will be straining its debt service capacity if it 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 also need to be considered.

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:

1. 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.
2. Sufficient land will be made available for the project from land previously committed to the Rice Project.
3. 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:

1. The project can contribute substantially to reducing unemployment in the Arecibo area while making an acceptable return on the investment.
2. 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.
3. 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

1-2 Background

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

The Puerto Rico sugar industry has declined over the past 30 years, becoming a mere shadow of itself. Meanwhile, 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.

However, the rum industry is threatened by a lack of sufficient domestic molasses, the basic feedstock for rum production, from the local sugar industry. Foreign suppliers now provide about 90% 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% 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 continue to rise as world oil consumption increases. This economic burden of importing oil for production of electrical power has placed severe restrictions on the Puerto Rican economy.

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, coupled with 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 for this is that over half of the new oil will have to be found in inhospitable areas such as in deep offshore waters and in the Arctic region. As a matter of fact, there is a strong...

The probability that the politics of the Middle East will continue to be both unstable and unpredictable is high. Therefore, it is likely that at some point within the next ten years, oil prices will begin to increase indefinitely at a faster rate than other prices. In brief, oil prices will surge quicker than the time it takes to install a large electric generating plant, and this increase will be painful for those who continue to depend on imports.

The economy of Puerto Rico is facing several challenges such as a declining sugar industry which produces about two-thirds of its sugar needs at a loss of $20 to $40 million per year. There is an insufficient domestic production of molasses for its viable rum industry, and the country imports oil for almost all of its energy needs. Unemployment is also a significant issue with a rate of 22 percent. In essence, the problems are the lack of domestic fuel for electrical production, insufficient domestic production of molasses for the rum industry, a non-economically viable sugar industry, and unemployment.

The Central Cambalache Mill, situated a few miles from Arecibo on the north central coast of Puerto Rico, processed sugar cane grown in the municipalities of Isabela, Quebradillas, Camuy, Hatillo, Arecibo, Barceloneta, Manati, Vega Baja, Vega Alta, Dorado, and Toa Baja. This area, a rectangular region 60 miles long by five miles wide or 300 square miles, is a nearly level to sloping coastal plain that includes the alluvial floodplains along the Arecibo, Manati, and Camuy rivers.

In the past, the main agricultural enterprise was sugar cane farming with some pineapple and dairy farming. Since the mill closed in 1961, the primary agricultural activities have been dairy, rice, and pineapple farming. In the 1950s, sugar cane was at the height of its reign in Puerto Rico, and the Cambalache Mill was the seventh largest of the 33 mills operating in that period. However, sugar production declined in the 1960s, and by 1969, the number of mills had decreased to 17, with Cambalache being sixth in the amount of cane processed.

The decline in sugar production, which began in the 1960s, continued without interruption through the 1970s. The Cambalache mill was the last in cane tonnage out of the seven mills still operating in 1981, the year it ground its last harvest. From a high of 39,273 tons of sugar produced in 1952-53, Central Cambalache only produced 11,080 tons in 1981. The mill faced not only a lack of cane but also low sugar content in the cane (5.9 percent), leading to its closure due to economic losses. The mill remains closed today, not because of inefficient operation, but rather because sugar cane growing is no longer profitable for the farmers in Cambalache.

The future of sugar cane in Puerto Rico looks bleak if the industry continues to focus only on growing sugar cane for sugar production, as it has done in the past. The 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 economically viable and probably never will be again. A completely 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 Rican sugar industry was struggling for survival, a group of agricultural scientists at the Center for Energy and Environment Research (CEER) at the University of Puerto Rico began to reevaluate the sugar cane plant. Led by Dr. Alex G. Alexander, head of the Biomass Division at CEER, the group studied sugar cane for its inherent potential to produce large quantities of dry matter (biomass). Traditionally, sugar cane had been bred and handled agronomically to produce only one product: sugar. These scientists removed the agronomic restrictions imposed by the sugar cane industry, opening up new possibilities for its use.

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 grasses (Pennisetum purpureum) 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. José 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.

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 a 16-month grand culture 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 can be obtained in the form of fiber for boiler fuel for electricity and fermentable solids for alcohol and sugar. The purpose of this study is to answer the question: Can sugar cane be grown and processed economically in the Cambalache area as a bio-sustainable 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 comprehensive feasibility study of a cane-based sugar-energy complex to be created at Arecibo, Puerto Rico, using as a nucleus the Cambalache Cane Mill which has been 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 conducting the study.

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. This was 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.

The project under study addresses all of the problems mentioned above. I propose 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.

The mill produces 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:

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:

1. 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.

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

3. 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.

4. Planting, harvesting, and transportation will be closely coordinated to take maximum advantage of the weather and minimize the waiting time of equipment and vehicles.

5. 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.

6. 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-round 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 In Audience

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 "supplementary Documents" for the specialists who wish to determine the basis of the findings and conclusions. Phase I of the proposal, which is given in this report, covered the period from September 17, 1984, to January 14, 1985, for field work, factory inspection, obtaining equipment specifications and

Prices and interviews were conducted for the period of January 15, 1985 to the present. This was done to ensure compatibility of findings and decisions across various sections in order to achieve the project's objectives. The economic analysis of proposals in the field, mill, and power sections were performed to complete the economic evaluation of Phase I. The final task was to write the completed report.

The work program of Phase I covered the following areas:

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.

BIOMASS COMMERCIALIZATION AT CAMBALACHE ENERGY CANE ENERGY GRASS FIELD FIELD GROWING GROWING, CUTTING CUTTING WHOLE CANE DRYING BALING IRRIGATION | DRYING & BALING WHOLE CANE | SUGAR CANE JUICE & BAGASSE | CLARIFICATION & EVAPORATION | STORAGE & BOILING HOUSE | LO ESRANUE ATION“ | CONDENSATE, SUGAR & MOLASSES TO MILL | POWER PLANT STEAM GENERATOR ELECTRICITY | STEAM TURBINE ELECTRIC GENERATOR | WATER & ELECTRICITY TO PREP.A. GRID

Power Plant Section: Turbogenerator evaluation, boiler evaluation and biomass supply.

Economic Section: Examination of the product market and analysis of the complex.

Recommendations: Construction and operation schedule.

Report writing and Printing

1.8 Organization of the study Team

The study team consisted of various qualified members of the CEER-UPR staff and consultants. They are listed below:

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
Consulting Engineer: Manuel Balzac

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

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2.0 AGRICULTURE

2.1 Introduction

Since Christopher Columbus brought the first seed to Puerto Rico in 1493, farmers have planted varieties of the plant genus Saccharum, commonly known as "sugar cane." Throughout history, it was the single most important economic product on the Island and the foundation of the economy from the 1920s through the 1950s.

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 a fundamental change in every component activity. This section of the report discusses the agricultural activities and resources required to support the Canbalache 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 yield (sucrose percent cane, by weight).

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- Use storable biomass such as cane trash, energy grasses, and rice husks to supplement cane bagasse and assure a year-round 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 was produced."

PR 980 was obtained from 17 acres of the José B. de Castro farm in Hatillo (2, p. 56). Planting and harvesting schedules along with transportation activities should be rationalized 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 intended for growing energy cane and grasses for Project CBCP spans a rectangular region, 60 miles long by five miles wide, or 300 square miles, on the north central coast of Puerto Rico. This area includes the municipalities of Isabela, Quebradilias, Camuy, Hatillo, Arecibo, Barceloneta, Manati, Vega Baja, Vega Alta, Dorado, and Toa Baja. This is approximately the area historically managed by the Cambalache mill, which peaked at 15,400 harvested acres in 1972. The mill is roughly in the middle of this area.

This area is a nearly level to sloping coastal plain and includes the alluvial flood plains along the Arecibo, Manati, and Camuy rivers. Currently, the main agricultural activities include 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 grains. 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, with Arecibo being the driest at 56 inches and Toa Baja the wettest at 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 the needs of the plant shows that, on average, there are deficits for the nine months from January to September, and in November. These rainfall deficits must be compensated by irrigation during six months of the year for optimal cane and grass growth. However, seasonal rainfall patterns vary by municipality. Close coordination of farm activities is required to ensure efficient use of resources.

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 acreage are: Bayanén 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, in terms of acreage, are deep soils with subsoil up to 60 inches deep. They are well-drained except for the Coloso and Sajura 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 acidic to acidic for most of the soils, ranging from 3.6 to 6.3. Most of the soils will require liming for better production. Organic matter content ranges from one to five percent in the topsoil.

2.2 Field Operations 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-round 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 tonnage rather than to use varieties that favor high tonnage 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 proper land preparation. Soil tilth to depths of 18 to 24 inches permits the energy cane plant's

Roots can 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 bed 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 soil 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 ensure the availability of the phosphorus to the nearby cane roots. The presence of nitrogen and potassium, also available in the fertilizer formula, ensures a good start for the young cane plant.

The roots of the plant emerge and grow. Soil and plant analyses will determine the correct amount of fertilizer to apply. Approximately 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 ensure healthy, vigorous seeds free of insects and disease. Seeds will be planted at a rate of 3.5 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. Overlapping double seed placement should be used to ensure 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 67-222, an introduced but as yet unused 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. 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 have not yet been determined.

The area is estimated at three acre-feet. High-tonnage production of energy cane or grass requires larger fertilizer amounts than those 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 ensure 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, a 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 larvae of Phylapnaga spp. and Diaprepes abbreviati) causing root damage; yellow aphids (Diaprepa abbreviatus adults) are major pests on cane foliage; cane stem borers and wireworms. Registered insecticides will be applied when necessary by tractor-mounted sprayers. Replanting of cane or grass will be done 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 tonnage (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.

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 supplemental boiler fuel. The ratoon crop requires as much attention as the plant crop. It is the crop that is the most profitable as it produces greater tonnage for the same inputs. Field operations should begin 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 ten 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 purpureum 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, producing 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. In addition to cutting, it also shatters the stem, ensuring an even faster solar drying. After cutting, the grass is windrowed with a tractor-drawn disc-type rake which collects and turns the grass into 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 growers who will be required to participate in this extension service program.

2.6 Land Requirement

The amount of land required for the production of energy cane depends on the capacity of the Cambalache mill, its downtime, 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 determines the milling capacity, which in turn determines the electric generating capacity. This, combined with grass yields, determines the grass acreage. All of these land requirements are imposed on an area that currently does not have a surplus of agricultural land. This area, which saw its cane acreage dwindle from 15,400 acres in 1972 to 9,200 in 1980, has experienced increases in dairy farming and cattle raising. It has also seen the beginning of a large rice-growing industry on lands previously dedicated to cane. In addition, some agricultural land has been repurposed for business, housing, industry, parks, roads, and schools over the past several decades.

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. However, the maximum yield of 121 tons of whole cane per acre obtained at Hatillo 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 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. 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 possibility (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. This 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 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 farmland, 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; Toa Baja, 3,000; Manati, 3,000; Vega 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 leaseholders of this land may resist the change from their present agricultural enterprise to that of an unfamiliar 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

The text likely should read:

It probably will not result in an economic operation for energy cane on larger acreages, 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 ranging from five to eight months. This assumes good production (85 short tons and 59 short tons per acre per year respectively) and average production (66 tons and 47 tons). The total acreage required varies little with 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. For grass, it's 20 percent less, but total requirements for land in farms is 27 percent higher. The acres in cane and grass respectively 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.

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The costs are divided into categories such as crop (plant and ratoon) and grass, respectively. As much as possible, these are economic costs, meaning that market prices or market-based costs are used, and subsidies are 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 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, farmland 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 $2.00 per ton. Total delivered cost is $1,405 per acre or $16.51 per ton. The most

The most costly operations are harvesting, at $298 or $2.50 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. Hence, the year-to-year spread in per-ton costs will be somewhat greater than indicated above.

The above costs are higher than those shown for energy cane and sugarcane in other sources. 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 other sources.

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 $2,300 or $22.03. The plant crop of energy grass costs $935 per acre or $31.70 per ton as compared to $592 or $20.10 for the ratoon crop. The highest costs are for irrigation and fertilizers. Harvesting costs at $62 per acre or $2.31 per ton, for mowing, raking and baling, are much 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.

Both energy cane and grass require careful attention to drainage, irrigation, soil preparation, fertilizers, and the choice of varieties. This can enable average yields of up to 85 tons of whole energy cane and 59 tons of energy grass per acre per year, meeting the requirements for energy-cane feedstock and energy grass as boiler fuel when the mill is not grinding. Studies of the area's soils and topography show that about 14,000 acres of land are suitable for energy cane and grass, in addition to lands previously committed to the Rice Project. Since this project requires at least 15,000 acres of farmland, top priority in Phase II should be given to determining land availability and the impact of farm location on the harvest season.

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

- Determine land availability as previously described.
- Prepare schedules for expansion of cropland 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, transportation, 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 optimal 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.

The text appears to be heavily corrupted, making it impossible to provide a comprehensive correction. However, the readable and meaningful parts can be corrected as follows:

"Machine damage to stool: © Define fertilizer application techniques. 32
In conclusion, there is enough suitable land for the project within an economic distance from the mill. However, not all of it is likely to 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. This will require changes in the traditional work schedule. The training of farmers by extension personnel is of great importance to the success of the project. Farmers must learn how to grow energy cane and energy grass as a new crop rather than repeat traditional sugar operations.

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"Of Energy, July 1982, 160 pp., and predecessor reports. 3. Méndez, J.A. et al. "Informe al Senado de Puerto Rico sobre Resolucion del Senado 420," Comision de Agricultura y Recursos Naturales, San Juan, 13 de febrero de 1983, 93 pp. 4. Abreu, E. et al. “Conjunto Tecnológico para la Producción de caña de Azucar," publicación 103 (revisada) Estacion Experimental Agricola, Universidad de Puerto Rico, Rio Piedras, octubre de 1963, 30 pp. 5. Calero-Bermidez, N. et al. "Informe a la Camara de Representantes de Puerto Rico sobre Resolución de la Camara 124," Comision de Agricultura, San Juan, marzo de 1982, 121 pp. 6. Anon, "Proposal for the Study of Biomass Commercialization at Cambalache, Arecibo, Puerto Rico," Center for Energy and Environment Research, University of Puerto Rico, Rio Piedras, May 7, 1984, 28 pp. 7. Morens, A.A. "Ingresos y Gastos en la Producción de Caña de Azucar en el Distrito de Riego del Valle de Lajas," Publicación 140, Estación Experimental Agricola, Universidad de Puerto Rico, Rio Piedras, febrero de 1981, 10 paginas.

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, fibrous, 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 Cambalache (5) cane 1971-1980 medians

Moisture 68 under 74% 73-74%

Fiber 16

Soluble solids under 14 10% 10-14%

*Equals (median percent pol 1971-80) 79.3%

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 collections of machinery are 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 2 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 piel 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 with Hilo-type unloaders. The cane then goes to a modern washing plant where it is cleaned in a Corning-drum pressure water-washing system. The juice is extracted by alternately wetting the cane with water and cane juice.

Juice is extracted by squeezing it between grooved steel rollers, similar to the wringing of a sponge. The rollers are grouped in sets, usually three per mill, and the mills (not to be confused with the entire processing plant) are laid out in a row called a "mill tandem." The rollers are typically powered by steam turbines, steam piston engines of the Corliss-type (as at Cembalache), or electric motors.

Prepared cane enters one end of the tandem, passes from mill to mill and comes out the other end as bagasse. The cane juice is collected from underneath the tandem and is carried away for purification, evaporation, and sucrose extraction. Energy cane will appear clearer than sugar cane due to 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:

1. Clarification (purification with lime and heat) to remove impurities.
2. 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 (miel) of about 65 percent soluble solids and 95 percent water.

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

4. Centrifuging to extract the sugar crystals in the 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 weaker molasses (4).

About 60 percent of the sucrose in the cane juice is extracted in the first pass or "raw sugar." The importance of crystallization and recovery of the sucrose in the syrup is paramount in these stages.

The production of raw sugar is usually carried out by a cyclical process. These stages are critical because their efficiency determines the amount of sucrose recovered and the amount left in the molasses in each strike. The usual process in modern raw sugar production uses the 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, as well as 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.

The first molasses is then moved to the second strike vacuum pan where another crystallization takes place. 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 strikes are deposited in tanks called crystallizers. Here, 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 pounds psig) from the exhausts of steam-powered mill equipment and vacuum-jet vapors from multiple effect systems. Also,

Most steam and vapors are condensed and returned to the boiler as water. However, with the three-strike system, the energy requirements for juice processing are large enough to require extraction of a significant amount of steam from the turbine section of the 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 significantly simplified 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 be 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 grown 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:

M3: 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.

M4: Typical steam balance for one strike ("A") sugar, obtained as in Table M-3.

M5: Typical steam balance for one-strike ("A") sugar obtained from milling 3,600 tons per day of whole 16.6 percent-fiber energy cane (fiber equivalent of above clean cane), with new power plant. In regard to this...

Referring to these tables, note that from 1972 through 1978, Cambalache milled cane at an effective rate which varied from 4,416 tons per day in 1972 to 4,824 tons in 1975, with a median of 4,622 tons (3, p. 67). As a point of departure, the Project assumes a target rate with traditional cane of 4,200 tons, or 91 percent of the median. Since operating parameters are proportional to fiber content (6), the equivalent 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: 56

Table M-2 STEAM REQUIREMENTS AND ENERGY FOR EXPORT

Average steam requirements' (lb per hour, by pressure)

150 psig 80,900 80,900 80,900

16 psig gross 173,900 153,300 252,300

less exhaust (27,700) (77,700) (77,700)

net 96,600 75,600 75,600

Average export energy (MW per hour) 735 29,800#

* Mill equipment only. Excludes electricity generation and turbine extraction

** 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

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, the energy available for sale increases more than 25 fold. The main reason for this is that the energy at these pressures has three components: the energy required to heat water to its boiling point (which increases with pressure), the energy to convert water to steam (the energy of phase change), and the "superheat" 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 traditionally used 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, the 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 a few miles to the north by the Atlantic Ocean. As a result, some equipment such as the Hilo-type unloader 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..."

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 expenses 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

This report's "Documents" section discusses various cane mill valuation methods and calculates numerous estimates. The analysis concludes with the expert opinion of Mariano A. Romaguera, a Professional Engineer, as follows: "After careful consideration of all factors involved in the valuation of machinery and equipment, fixtures, and leasehold improvements, we believe that the market value of the Cambalache Cane Mill, excluding land, as of November 1984, is approximately $3,600,000 (three million six hundred thousand dollars)."

This project presents an opportunity to repurpose the mill rather than scrapping it. No value is assigned to the land because even if all the removable items of value were sold for scrap, significant expense would be incurred to make the land usable for another purpose.

3.10 Work to be Done in Phase II and III: Work during these phases will include tasks as described in subsection 6 of the next section.

TABLE Ha: TYPICAL STEAM BALANCE (SIMPLIFIED) THREE-STRIKE FROM TRADITIONAL CLEAN CANE CAMBALACHE MILL WITH EXISTING BOILERS AND TURBOGENERATORS

Composition of cane and bagasse:

Clean Cane: Short tons § Water: 3,108
Fiber: 612
Soluble solids: 4039.6
Total per day: 4,200
Per hour: 175

Bagasse: Short tons § Water: 75.9
Fiber: 16.0
Soluble solids: 43
Total per day: 1874
Per hour: 618

Heat content of bagasse:

BTU per pound: 48,099
Million BTU per short ton: 8.199
Per day: 12,085
Per hour: 503.5

A. Sixemill tandem (28 short tons of Fiber) x 110 by/ton x 25 lb/mp x 1054 Aw/mr: 60,850
B. Electricity generation (for Mill use only) (175 short tons of clean cane) x 42 kew/ton x 1358 x 100 lb/kew: ato c
C. Subtotal Yo/mr: 194,250
D. Boiler auxiliaries:
1. Forced draft blowers Subtotal III.c. x 1.658: 3,205

Continued Table M-3 - Page 2

B. Services
2. Boiler feed water system and emergency live steam system
Subtotal III.c. x 1.35%: 2,622
Emergency makeup steam Subtotal III.c. x 5.5%: 10,683
Subtotal Ab/mr: 210,760

Losses:
1. Radiation Subtotal II1.F x 10$ = 21,076
2. Other Subtotal IIZ.F x 54 = a.538

Total requirement for steam at 150 psig:
1. Average requirement Ab/ar = 282,378
2. Operational flexibility desired Average x 10% = -2h2ar
3. Peak requirement (rounded) Ib/nr = 266,600
4. Boiler capacity installed = 354,000
5. Excess capacity installed under peak conditions (rounded) = 354,000 lb/hr - 266,600 lb/nr = St.400

Energy equivalent of average requirements:
1. Energy in steam Bru/ib = 1,227 Billion BTU/hr = 297.4
2. Average boiler efficiency = sen
3. Energy required in fuel million BTU/hr = $71.9
4. Energy in fuel (61.4 short tons bagasse x 8.199 million BTY/ton) = 503.8

Conversion from BTU to be made up by burning a supplementary fuel, 8: 11 barrels of No. 6 (residual) oil fuel per hour = 62.

Water Clarifier lb/ar = 13,230
Pre-evaporator = 126,000

C. Vacuum pan makeup = 184,900
Ab/nr = 126,000 lb/nr
1.900 > Subtotal lb/nr = 158,130

E. Losses Subtotal x 108 = 1g
F. Total requirement for exhaust steam at 16 psig
1. Average requirement Bar = 173,983
2. Operational flexibility desired Average x 105 = 1398
3. Peak requirement (rounded) = 191,300

A. Exhaust available from prime movers under peak conditions Subtotal IIT.F x 110% x 96% (rounded) = 222,600

5. Excess exhaust steam under peak conditions (rounded) = 222,600 lb/nr - 191,300 lb/ar = 31,309

Y. Requirement for hot vapor at 628 psig sat:
A. Secondary lime-reduced heaters lb/ar = 18,480
Vacuum pans = 59,640
Make up to secondary vapors from first body (first evaporator)*

Total requirement for hot vapor:
1. Average requirement lb/hr = 93,385
2. Operational flexibility desired Average x 105 = 336
3. Peak requirement (rounded) lb/hr = 102,700

*Vapors from first body (first evaporator in primary cane juice heater. F) utilized for juice heating = 63

Continued Table H-3.- Page & 4
Vapor available from pre-evaporator under peak conditions (see IV 8) = 126,000 lb/hr x 110% x 60% (rounded) = 83,200

5. Deficit of vapor available under peak conditions (rounded) = 83,200 lb/hr - 102,700 lb/hr

£19,590. IT Requirements for hot vapor at 4 psig sat.

A. Primary juice heater Ab/nr 4860
Total requirement for hot vapor
1. Average requirement, Bo/ae 38,860
2. Operational flexibility desired (Average x 10%)
3. Peak requirement (rounded) iver 36,300
4. Vapors from first body under peak conditions (rounded) 21,600
5. Ratio in vapor available under peak conditions (rounded) 21,600 lb/hr = 38,300 lb/hr
Amount (16,700) to be made up from reducing valve, excess exhaust steam (IV.B.5) by means of pressure 64

TABLE No. TYPICAL STEAM BALANCE (SIMPLIFIED) ONE STRIKE (A) SUGAR FROM TRADITIONAL CLEAN CANE. CAMBALACHE MILL WITH EXISTING BOILERS AND TURBOGENERATORS:

1. Composition of cane and PA245°C(see Table M=1)
TH. Heat content of bagasse (see Table 4-3)
TY. Requirement for steam at 150 psig, 415 deg F

A. Six mill tandem (see Table H-3, TI.A.) lb/hr 80,850
B. Electricity generation
   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 80 lb/kW 29,400
c. Subtotal lb/hr 198,250
D. Boiler auxiliaries and emergency makeup steam (see Table M-3, ITI. D and 8) 16,510
E. Subtotal lb/hr 210,760
Losses (see Table H-3, IIT, G) A618
G. Total requirement for steam at 150 psig
   1. Average requirement lb/hr 22,378
   2. Operational flexibility (Average x 10%)
   3. Peak requirement (rounded) lb/hr 266,600
   4. Boiler capacity installed 358,000
   5. Exhaust capacity installed at peak (rounded) BL.400

TV. 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 H-3, IV. B) 126,000
C. Vacuum pan makeup —
D. Subtotal lb/hr 139,320
E. Losses (Subtotal x 10%)
Reduction is due to smaller loads on centrifugal, water pumps, and other equipment.

Continued Table Net - Page 2
1. Operational flexibility desired (10%)
2. Total requirement for exhaust steam at 16 psig
3. Average requirement
4. Peak requirement (rounded) lb/hr under peak

The following text has been corrected for readability:

Conditions: Subtotal 121.8 (refer to this table) x M04 x 96 (rounded) at line 5. Excess exhaust under peak conditions (rounded) 6. 222,600 lb/hr = 168,600 lb/hr. Reduction in average requirements, see Table M3, TV. Pt (rounded) 153,300 lb/hr = 173,900 lb/hr.

A. Secondary Lined - juice heater (see Table #3, Y, A.).
B. Is there a static vacuum pan?
C. Make up to secondary vapor from the first body (first evaporator).

D. Total requirement for hot vapor at 6-8 psi:
1. Average requirement.
2. Operational flexibility desired (10%).
3. Peak requirement (rounded).
4. Vapor available from the pre-evaporator under peak conditions (see Table 103, VD).
5. 83,200 lb/hr = 65,600.
6. Reduction in average requirements, see Table M3, 7. D.1 (rounded) 59,600 lb/hr = 93,300.
7. Actually, two pans will be drawing hot vapor. Must be vented to the atmosphere.
8. Excess of vapor under peak conditions (rounded): 153,252 - 15,325 - 168,600 - 222,600 - 54,000 - 11,600 - 26,775 - 59,600 - 65,600 - 83,200 - 11,600.

The system can be used in offset cycles, but only one at a time.

TABLE M5, TYPICAL STEAM BALANCE (SIMPLIFIED) ONE-STRIKE (A) SUGAR FROM WHOLE ENERGY CANE CAMBALACHE MILL PLUS NEW POWER PLANT.

1. Consumption of cane, bagasse and trash:
Whole Cane: 3600 short tons/day, 150 short tons/hr.
Bagasse: 1483 short tons/day, 62 short tons/hr.
Trash: 214 short tons/day, 9 short tons/hr.

2. Heat content of bagasse and trash:
Bagasse: 4266 BTU per lb, 8.532 million BTU per short ton, 12,653 million BTU per day, 527.2 million BTU per hour.
Trash: 6672 BTU per lb, 13.344 million BTU per short ton.

3. Requirement for steam at 150 psi, 415 degrees F:
A. Semi-standby (see Table #3, III, 4): 80,850 lb/hr.
B. Total requirement for steam at 150 psi:
1. Average requirement: 80,850 lb/hr.
2. Operational flexibility (10%): 8085 lb/hr.
3. Peak requirement: 28,990 lb/hr.

Note: Non-combustible solids are two-thirds of the field production. The heating value is per Havasian version of Hessey's formula. There is no change in the amount of fiber per hour. The steam or electricity generation is within the mill. All energy is used.

The text has been corrected as follows:

The mill obtains from Poner Plants 67.

Continued Table M-5 - Page 2

IV. Total requirement for exhaust steam at 16 psig sat:

1. Average requirement (see Table Not, IV. F.1) lb/hr 183,252

2. Operational Flexibility desired (10%) 15,325
3. Peak requirement (rounded) 168,600

A. 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 = 83,200 (see Table 4-8, V) (see Table #23, VI)

TABLE HA IMPROVEMENTS AND REPAIRS TO MILL IN PROJECT YEAR ONE

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 200

Subtotal (Item 1-4) 1020.0

New "Silver CoS" shredder with 1,000 hp turbine drive (or heavy-duty electric rotor) and substation equipment (delivered) 1 240,000

Installation, foundation and feed conveyor lump sum

Subtotal (shredder) 240,000

6. Fuel handling and storage facilities:
   Conveyers for bagasse and/or chopped grass (linear feet) 240 300 12.0
   Storage building (60 x 120 x 24) space and return conveyor, lump sum 20

Subtotal (fuel facilities) 80

7. Weighing scale 6,000 86
8. Sugar centrifuges 3 90,000 180

Subtotal (items 1-6) 1798.0

9. Overhead and inspections items 1-8,7,8 108 121,000
   Items 5-6 * 29,000

Subtotal (overhead) 150.0

Total (items 1-9) 1,988.0

This is an addition to existing equipment. Does not include machinery for breaking up bales of grass 69.

TABLE M- ESTIMATED MILL PAYROLL AT CAPACITY OPERATION

No. | Description | $/Hour/Person | $/Month/Person | Annual $ /Person

1. Administrative personnel
   Chief engineer | 2,330 | 28,000
   Asst. engineer | 2,670 | 20,000
   Chief chemist | 1,830 | 22,000
   Asst. chemist | 1,000

12/000 is Eric, an Instrument Expert Engineer with a salary of 170 and a clerk with a salary of 24/009. The subtotal for these employees is 8,500 which brings the total to 126,500.

In the milling laboratory, we have Jason as a personnel with 2 laboratory analysts earning 800 each and a subtotal of 18,200. We also have a sampler earning 3.95, bringing the subtotal to 15,500.

In the cane yard, we have 2 foremen earning 950 each, a cane analyst/core sampler earning 800, 2 assistant analysts earning 4.5 each, 2 payload operators earning 450 each, 2 crane operators earning 33,500 each, 4 utility personnel earning 85,300 each, and 1 utility person earning 35,200. The subtotal for these employees is 185,500.

In the washing plant, we have 1 foreman earning 700 and 2 console operators earning 3.95 each. The subtotal for these employees is 47,000.

They work 40 hours/week and all receive lodging as well, except for a few exceptions. Personnel is based on 164 effective operating days; 8 hours/shift and no overtime.

Continued on Table M-7 - Page 2, in the milling tandem we have a foreman, mill feeder, operator, oiler, and plate cleaner. In the filter, evaporation, and vacuum section, we have 2 vacuum pan operators, 2 vacuum pan assistants, and 3 utility personnel. In the centrifugals and weighing station, we have 3 utility personnel/weighers.

Continued on Table M-7 - Page 3, in the machine shop, we have a foreman earning 900, a lathe operator earning 5.00, an assistant earning 11, a carpenter earning 3195, and a helper. The subtotal for these employees is 113,200.

In the summary of payroll expenses table, the administrative costs for project years 1-5 are 126,500; Laboratory costs are 200,35/700; Cane yard costs are 89,200 and Washing plant costs are 31/509.

(Note: The text seems to be a mix of different figures and doesn't give a clear context or complete information. The above interpretation is made based on the given text and might not be 100% accurate.)

Miscellaneous 34/800 32,000 86,800 - Machine shop 54,109, 58,500. 113/209 subtotal 680,600 407,100 2,087,700 overtime” a. 85,800 85,800 - Subtotal 680, 600 492,900 2,373,500 Fringe benefits? 17; 0 0, 74 Total 918, 200 665, 400 1,584,200 . $/short ton* 2.127 2.683 Project years

6-255 Total 736,700 574,900 1,312, 600 $/short ton* 0.974 1.980 with existing boilers and turbo generators. Equals total net payroll x 108. Equals last subtotal x 35%. Includes vacations. Based on 164 effective days/year and 1,600 tons/day of whole cane. Reflects closing of Washing Plant and transfer of energy production to Power Plant.

TABLE M-9. ESTIMATED MILL OPERATING AND MAINTENANCE EXPENSE AT CAPACITY OPERATION

Expense | Average | Project years 1-5
Payroll expense | 918,800 | 665,400 | 1,884,200
Other operating expense | 248,100 | 179,600 | 427,700
Maintenance expense | 97,400 | 402,609 | 3,300, 000
Total | 1,264,300 | 2,247,600 | 3,512,900
$/short ton | 3.807 | 5.948

Project years 6-25
Payroll expense | 736,700 | 574,900 | 2,322, 600
Other operating expense | 198,900 | 155,200 | 354,100
Maintenance expense | 73,000 | 052,000 | 25,000
Total | 1,008,600 | 2,782,200 | 2,790,700
$/short ton | 3.018 | 4.727

Again, with existing boilers and turbo generators. Allocated in proportion to payroll expense. Allocated by difference. Total estimated independently. Based on 164 effective days/year and 3,600 tons/day. Reflects closing of Washing Plant and transfer of steam and electric generation to Power Plant. Annual average equals 75% of average for years 1-5.

2.12 References cited

1. Alexander, A.G. Sugarcane Physiology: A study of the saccharum Source-to-sink System, Elsevier scientific publishing, Amsterdam, 1973, 752 pp.

2. Hugot, E. Handbook of Cane Engineering (second edition), Elsevier Scientific Publishing Co., Amsterdam, 1972, 1079 pp.

3. Samuels, G. "Puerto Rico sugar Industry operations 1971-80 - A Data Base," Center for Energy and Environment Research, University of Puerto Rico.

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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 crystallization 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 450 pounds per square inch above atmospheric pressure (psig), a

The temperature is 900 degrees Fahrenheit (deg F), and a calorific value of 1,454 British thermal units per pound of steam (BTU/1b). This is when operating 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 million, excluding charges for the use of funds invested. Construction time, including preparation of final designs, obtaining 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, 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.

Electricity in the traditional sugar industry often sees irregular and sometimes unpredictable cane deliveries. However, under the project, deliveries are expected to be quite smooth due to the significantly improved coordination of planting, harvesting, and transportation. When supplementary fuels are continuously available during the milling season, there is a 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. This means determining whether it is better to add a bit more capacity to the biomass power plant or to some conventional fossil fuel generating station elsewhere.

However, land requirements are still uncertain due to 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% 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 averages 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 215,000 pounds per hour, providing an operating margin equal to 10.8%. The capacity and other parameters of the 76 follow from this and from the extraction needs. The 76

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 trade-off 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.

4.9 Capacity Splitting

Although most of the major equipment used in the mill and plant are not "off the shelf," all of them have basic designs. 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, between two TC'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 generators 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 Rincon Nuclear Plant, the possible use of one of these units in conjunction with a small new generator 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 generator of 20,000 kW in conjunction with a new, double extracting/condensing unit of 20,500 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 the next phase.

Phase II for the following reasons:

* The initial investment required for Alternative B is $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 16'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 Xu). Most steam for mill use must be passed through and extracted from the new 7G. The high unit cost of a small, double-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 increment 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 76's instead of one. The used 76 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 G'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 16 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 historical 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 (vt-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 (e.4.f, San Juan) $5,500,000. The scope of supply for the quotations includes the boiler itself, air heaters, controls and instrumentation, an economizer, feed pumps and drives, a forced-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 traveling 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 16 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 MW as appropriate. The Brown Boveri estimate was also increased 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 (2). A closed loop, circulating water system with cooling tower is mandatory for the 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 evaporation and the system will not be affected 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"

"Meeting peak demands or functioning as a 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. Furthermore, the plant will operate at pressure and temperature well above those used for sugar milling, but within the lower part of the range traditional for electric generation. Simultaneously, 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 fluctuations and occasional interruptions, both planned and unplanned. This operation utilizes steam of intermediate pressure (150 psig). Part of the low-pressure steam (16 psig) used 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 degrees Fahrenheit has been selected due to the aforementioned circumstances. Economics alone would probably dictate a pressure of 1,250 psig, but this pressure is inadvisable from an operational standpoint.

Everyone connected with the Cambalache project must be conscious of these factors and what they imply for operations. In particular, a much greater degree of care, efficiency, and maintenance is required than was customary in the old sugar industry. Sloppiness and carelessness cannot be tolerated because they can be expensive and dangerous.

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 16 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, this involves the creation of a new cane industry."

Puerto Rico is not an agronomic, financial, or technological 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 3 (bagasse fuel) and 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 including both total and estimated.
- Milling: 182 days (actual), 309 days (estimated)
- Non-milling season: 163 days (actual), 136 days (estimated)
- Subtotal: 325 days (actual), 309 days (estimated)
- Maintenance period: 40 days (actual), 56 days (estimated)
- Total: 365 days (estimated)

The plant will operate on bagasse and fallen cane trash for 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

Erosion, Herbicides, and Pesticides: Reduction in airborne particulates. Impact of heavy equipment on soils. Improvements to soil from better preparation and more frequent planting. Management and personnel. Financing and organization.

Unfortunately, the following text is illegible and cannot be accurately corrected without further context.

Again, the text provided is unclear and lacks context to be accurately corrected.

Table of Power Plant Summary:

Operating Plant = Bagasse Fuel (164 Effective Days)

Unit Type	Average Operating Hour	Weight of Fuel (As Fired)	High Heating Value of Fuel
Bagasse		Short tons	Million BTU's
Fallen Cane Trash		YW	
Total			

Please provide the missing data for a complete table.

Boiler Efficiency: Steam produced at 950 psig, 900 deg F. Energy content in million BTU's, BTU/Ib steam weight from Table M-5, number 62 is 527.2, 219.0, 66.2, 8643, 413.6, 1,456, and 284,400 respectively.

Continued Table P-3 - page 2: Steam extracted at 160 psig, 415 deg F. Energy content in million BTU's is 99.0, BTU/Ib steam weight is 2,223, total weight is 80,900. Steam extracted at 16 psig is saturated. Energy content in million BTU's is 83.8, BTU/Ib is 1,209, total weight is 75,600. Steam condensed or lost, energy content in million BTU's is 230.8, less electricity generated is 77. Net is 153.6, BTU/Ib is 2,202, total weight is 127,900.

Electricity gross generation is 22,600, mill use is (2,900), export to PREPA is 19,800. *Allows for a 10 psig pressure drop, 922,620 KW x 3,612 BTU/KW = 44 x gross generation 95 in rotor and Mill tandem.

Continued Table P-2 - page 3: Selected rates are, boiler steam/biomass a/b is 2.00, boiler steam/electricity Ib/gross KW is 12.58. Electricity/biomass gross KW/ton air export Ki/acre is 11,200. Average effective operating day (24 hours), weight of fuel (as fired) bagasse short tons is 2,483, fallen cane trash is 24, total is 1,697.

Electricity exports (rounded) Xi hours is 475,000 (164 effective operating days on cane biomass). Weight of fuel (as fired) bagasse short tons is 243,200, fallen cane trash is 7 and total is 25,200. Cane equivalent short tons is 590,400. Acreage equivalent (rounded) acres is 6,950. Electricity exports in thousand KWH is 77,933.

Table P-4 Summary Operating Plan - Grass Fuel (245 Days): Unit type and number, average operating hour, weight of fuel (as fired) energy grass short tons is 45. High heating value of fuel energy grass in million BTU is 525.5. Boiler efficiency is as is. Steam produced at 850 psig, 900 deg F. Energy content in million BTU is 336.3, BTU/Ib is 1,454, weight is 231/300.

Steam condensed or lost, energy content in 5 million BTU, less electricity generated. Net is 50, BTU/Ib weight is as is. Fat moisture content is 11.6722 million BTU/ton, 726,500 KW x 3,432 BTU/KW.

Continued Table P-4 - Page 2
Unit Type
Number: Electricity Gross Generation XW: 26,500
Mill Use: -200
Plant Use: -1,100
Total: $3,300
Export to PREPA: Selected Ratios
Boiler Steam/Biomass lb: 2.57
Boiler Steam/Electricity lb/gross KW: 8.73
Electricity/Biomass gross Ki/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: 604,800
44 percent of gross generation: 98

Continued Table P-4 - Page 3
Unit Type 9, in the milling season and ling season
Weight of fuel (as fired)
Energy grass short tons
Weight of fuel (as harvested)
Energy grass short tons
Acreage equivalent (rounded): acres
Electricity exports thousand Kwit at 67.4 percent moisture
Sat: 59 tons/acre
Number: 156,600
336,300
5,700
87,696

References Cited:
Corlett, O.B. "Understanding the Currency Cane Line Selection and Opinion," Arnold Bernhard & Co., New York, September 9, 1983, pp. 54+.
Reason, J. "On-the-Job Training is No Training," p 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 a feasible alternative for commercialization at Cambalache. More than anything else, the answer to this question depends on 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

The maximum price for purchased power will remain around 5.4 cents per kWh. This is the incremental cost of adding lead 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 the initial investment per kW is substantially lower and/or specialized financing (such as Urban Development Assistance 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 1990s" (22, p. 26). If the growth of peak demand approaches 2.0 percent, new capacity on the order of 200 MW will be needed early in the next decade (20).

Assuming adequate growth in the demand for electricity, a viable design for the project does exist. Many of its parameters have been described and analyzed in the previous section. This section completes the task 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 the calculation of present values, internal rates of return, and similar measures. Following are key results of...

The economic analysis © Without the benefit of inflation or subsidies, the project generates a positive cash flow from operations beginning in the 3rd 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 Year. 2-5 Year. 6-25 Year. 1-25
$000 $000 $000
Operations (367) 4,227 3,312
Investment 6,920 1,388
Total (7,286) 4,227 1,926

Net cash outlays during the first five years of the Project's Life total $6.4 million, of which $34.7 million represents the initial investment and $1.7 million, the net loss from operations. During the first 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 equals the sum of the inflation-free internal rate of return of 7.7 percent calculated from Table E-1 and investors' current average expectations of future inflation of 4-5 percent.

This compares favorably with the 10 percent yield to maturity currently quoted for PREPA bonds with a life of 20 years to redemption. 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 reserves. The comparable market rate, calculated from Table E-2, is 18 percent versus the 15 percent (before income taxes) used by JSH. The comparable inflation-free rates are 7.7 percent and less than 9.9 percent respectively.

JSH rates assume an increase in energy prices equivalent 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 equivalent of 563 direct full-time jobs (50 weeks per year, 40 hours per week), as shown below. The estimates below include transportation and service of agricultural machinery and the transportation of crops but exclude the transportation of sugar and molasses. Source: Government Development Bank for Puerto Rico.

TABLE E-2 EMPLOYMENT SUMMARY

Full-time Planted Harvest equivalent jobs

References Sector acres interval Total Per 1,000 Section Tables (mo.) acres

Agriculture cane 6,950 82 175 85 B0 ACL, A+2, Ax!
Grass 52,700 6 23,341 B0 AA3, ACa

Subtotal, 127,650 407 E crop transportation 37 BYE Ari to a-g (40 ton trucks) BL

Subtotal, 22,650 44a 38 Mill & Power Plant

Total 563

Indirect employment is estimated at 624 full-time equivalents and total employment at 1,197, using type II multiplier of 1.52 for agriculture, 1.70 for transportation and 4.93 for the mill and power plant (4, 1978, p.351).

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

Except for the choice of "AY sugar" and consideration of two TG's instead of one (Alternative B on page 0), there has been no attempt to optimize the project conceptual design. In brief, there is room for improvement.

With the two exceptions indicated below, there are no price changes from 1984 during the twenty-five years of the project's life. Neither change assumes any change in the price of petroleum. Since both the 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.

The text reflects a gradual increase in PREPA's "avoided cost" (See table E-3, page 5). The price of sugar declines from 22 cents to 11 cents, reflecting 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 AFE/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 price except for irrigation water, which is not sold commercially and is valued at the market price of the inputs required to use it on the crops. Its cost at the edge of the field is estimated at 20 cents per 2,000 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.

For the purposes of this study, it is convenient to define economics as the art and science which describes, analyzes and evaluates those trade-offs 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, as these tend to be numerous. Projects such as the one under study are classic illustrations of monetizable trade-offs. In this regard, they resemble thermodynamic systems.

The system suggests that a project can be conceived of as a system with boundaries, across which energy and matter move, measured in terms of money as well as hours, tons, and so on. However, unlike the typical thermodynamic systems analyzed in texts, no common physical 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 clear-cut trade-off 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 outflows 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 monetized.

At first glance, project evaluation would seem to be a straightforward problem for a microcomputer spreadsheet program, but in reality, it is more complex.

The fact is not easy. 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. Should market prices be used? These may not always exist or may be distorted by lack of competition, government regulation, etc.

Or should "shadow prices" be used? 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 potential considerations...

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

Section 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. The analysis follows and is based on the feasible case summarized in Table E-3 and on the previously stated assumptions.

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 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 independent projection of the general rate of inflation more than a few years in the future. Moreover, over twenty-five years, the inflation rates for individual project inputs and outputs are liable to diverge, and these divergences are likely 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.

Expectations of future inflation are extracted 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 prices of electricity and 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 Sweeteners." 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 days in years 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 clearly shows 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

People generally prefer now to later. If they must postpone something which they desire or need, they want to be compensated for it. Hence, if the 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. An example of this is the prepublication discount on a book. Conversely, if payment lags delivery, an extra charge may be in order, like the finance charge on 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 their property back until sometime in the future. Most people require some (although not very much) monetary incentive to save a little and a strong incentive to save a lot.

The situation regarding 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 an 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 averse 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...

The following text is made in the hope of securing a return on, and the recovery of the amount invested, via a page 43 break. 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's apparent that this trade-off between the present and the future, this time preference of human beings, is a natural phenomenon. It's not the invention of usurers or 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.

Given enough stability in prices and 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 a stream of flows as of the first day of a project life of (t) periods, the cash flow corresponding to each period 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 also be 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.

The rate 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 adjusted flows equal to zero. Moreover, the net cash flows can be invested at rate 4 in existing financial markets, as assumed by the 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).

At the same time, wide variations in rates of return on investment (12) and the rate 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, hand tools 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 the sixth year, approximately 60 percent of Project revenues are expected to be earned by the sale of electricity. The third issue is relevant, however, since Table E-2 uses constant prices, and the 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 Internal Rate of Return (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. The geometric average of the Laspeyres and Paasche indexes of the Project's product prices, referred to as the Fisher "ideal" index (13), shows an average annual decrease of only 0.6 percent compounded 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 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

The 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). Another approach is to evaluate an appropriate energy-industry cash flow, such as that of JSH, which incorporates an inflation rate. Then, apply this inflation rate to the energy product prices in Table E-3 and compare the resulting IRR with the reference discount rate. This 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 thereafter.

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-2 gives an IRR of 18 percent for the life of the project, which compares very 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 appears because producing oil from existing wells is more risky than producing energy and other products from biomass. Both activities 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, due to technical problems in estimating oil well decline curves (15), the future...

The 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. 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

They subject 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, multi-product 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 versatile 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 growth 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.

In any location in the world, the demand for electricity in Puerto Rico is a derived demand. Electricity is not desired for itself but rather is an input to the production, distribution, and 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, there are 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 continuous-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 be 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 baseload units which is estimated at 5.4 cents per kWh for the purpose 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...

The text might be revised as follows:

The situation is liable to change significantly before the decade is over. If Section 936 of the U.S. Internal Revenue Code is eliminated, the economy of Puerto Rico could plunge into a deep depression. Small island economies, burdened with too many people and too few resources and distanced from large-volume, high-growth markets, often have to import much of the funds required for investment, regardless of their economic or political system. It may take ten years, with no guarantee of success, to reorient the industrial promotion program to Europe, Japan, and Latin America. Wage credits cannot bridge the gap between Puerto Rico and its low-wage competitors or provide the same volume of potential investment funds as Section 936. If Section 936 is eliminated, the excess of generating capacity will likely increase.

If Section 936 is preserved but business and government continue to operate as before, the current situation will continue to deteriorate until it becomes unbearable for the poor in Puerto Rico and the taxpayers on the mainland. Within a few years, a crisis of historic proportions might arise. However, the new administration of the Commonwealth has prioritized the creation of jobs and the preservation of Section 936, providing hope that the economy will grow based on productive activity. Economic growth often leads to an increase in electricity consumption, albeit at a slower rate. Therefore, if Section 936 is retained, an outcome like the one shown in Table E-9 is possible.

Although not directly shown, 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, at 2.2 percent per year, compared to an average annual decrease of 2.6 percent over the 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 members of the study team have worked on three proposals to present to the 358th Congress to save Section 936.

Replace section 931 with section 936.

The 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 the addition of 300 MW of coal-fired, base-load capacity in the fiscal year 1993-94, and again in 1994-95 (21, Cuadro 1). Also, 168 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 need 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 $2002 per gross kW, in 1984 prices. The total investment for a three-unit, 900 MW generating station is estimated at $1.6 billion or $1782 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 in 1984 was only $2.3 billion (historical cost). Moreover, after providing for current expenses, its total payments to various funds in the fiscal year 1983-84 as a result of contractual obligations were only $190 million (24). Thus, a move to coal, however attractive in terms of life cycle cost, could strain the organization's

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 and 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 the 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-1. 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.

Sugar Demand and Price: World consumption of sweeteners is more than 122 million short tons per year, of which 103 million short tons 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 sweeteners account for less than nine percent 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 income. From the producer's point of view...

View, raw sugar is a bulk commodity with no meaningful distinctions between cargo meeting trade standards for quality. All cane growers face lead times of twelve to eighteen months and, like most farmers, are vulnerable 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 use 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 sweetener 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 sweeteners. 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

Trade restrictions fairly limit sugar imports to the U.S., compensating for production deficiencies and maintaining the domestic price around 21 cents per pound. This price is significantly lower than the cost of producing sugar in Puerto Rico using traditional methods, which is estimated to be over 32 cents per pound. Given the current situation, there is little hope that Puerto Rico's traditional industry will ever be competitive again.

However, as long as the U.S. price remains above the world price, and there are other products to help offset manufacturing costs, the potential for producing sugar in Puerto Rico should not be completely dismissed. At 21 cents per pound of 96% pure raw sugar F.O.B at the mill, a pound of sucrose in sugar is worth over four times its value as just another fermentable solid in molasses, priced at 49 cents per gallon C.I.F. in 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 remaining amount was imported. Given these factors, and the significant contribution to joint costs made by electricity sales, production, and sales of sugar have been included in Table E-3, but at a price which declines from 22 cents to 11 cents per pound over ten years.

For a more detailed and comprehensive overview of the Puerto Rican, U.S., and world sweetener markets, please refer to "World Sweetener Markets" in the "Supplemental Documents" of this report.

The only continuous, organized markets are for blackstrap molasses (miel agotada or miel final), the residual liquid from traditional sugar manufacturing by the three- (or four-) strike system. As it exits the centrifuges, this product is too viscous for pumping or consumption. Depending on its intended use, it is diluted with water to trade standards. For animal feed, apparent soluble solids should be at least 79.5 percent (measured in 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 of 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 of blackstrap tends to be five to ten percentage points below the measured. However, 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, accounting for 76 percent of its usage. In the Caribbean, it is the only legal feedstock for the distillation of rum. 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. 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 have 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. Brazil, India, the Russian bloc, and the European Economic Community accounted for the largest 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.

The country of origin for animal feed and ethanol is significant. In 1983, the U.S. mainland’s consumption of all types of molasses for all purposes is estimated at 653 million gallons. Out of this, imports from foreign countries provided 276 million gallons or 42 percent. In the fiscal year

1982-83, Puerto Rico's consumption was 47.8 million gallons, of which 37.4 million gallons or 78 percent was imported at an average f.o.b. price of 36 cents per gallon. The balance of 10.6 million gallons was utilized, with about 6.0 million used for animal feed.

The 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. Blackstrap molasses, being a residual byproduct of a bulk commodity which is in world surplus, exhibits marked price fluctuations both in the long-term and short-term. From a high of 69 cents per gallon f.o.b. New Orleans in February of 1981, it fell to a low of 6 cents in November of 1982. It then recovered to 41 cents in October of 1983 where it remained until June 1984, gradually dropping to 29 cents where it remained until June 1985.

For the purpose 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. It also includes a 23 percent premium over the c.i.f. Price for its higher content of fermentable solids, along with a six percent premium on the adjusted c.i.f. price to represent the supplier's share of distillation economies. This includes 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 significant technical difficulties are anticipated in convincing local rum distilleries to use the former to replace at least part of their requirements for the latter. However, the Bacardi corporation must continue to buy.

Substantial quantities of blackstrap are needed due to a significant investment in an advanced design anaerobic digestor, which is designed to produce biogas for a 100,000 pound per hour boiler. Thus, a minimum supply of distillation slops, once considered to be only obnoxious waste, is required at all times. The main challenges anticipated in marketing project molasses involve assuring the security of the A molasses supply through long-term contracts and determining a mutually acceptable, flexible price formula. These issues will be further studied in Phase II.

5.10 Sensitivity Analysis

An important question in any project evaluation is: to what extent do key economic and financial results change when a significant assumption or parameter of the conceptual design changes? A comprehensive sensitivity analysis of the relationships between project variables and major assumptions will be undertaken in Phases II and III of this study. Nevertheless, some preliminary observations can be made based on 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 in Table E-5.

The project would lose money 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 expenditure.

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 becomes economically feasible.

A ten percent increase in the average cane yield per acre will increase the delivered cost of

Cane yields account for about six percent and 432.

The levelized annual economic cost of the project is about two percent. However, with the increase in electricity exports, sugar revenues, and other revenues, the required price of electricity should decline about 10 percent, to 0.9 cents per kilowatt-hour. 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 by 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, as 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 insensitive to changes in economic parameters relating to the initial investment. 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 benefit from inflation. A project with the same initial investment and revenue, where the latter are derived entirely from the sale of energy products, is likely to increase more slowly than the general rate of inflation. This is because the prices of sugar and molasses are likely to increase more slowly, so the price of electricity must increase faster for the two projects to show the same internal rate of return (IRR) in a given period. For example, if the general inflation rate is ten percent and the rate for sugar and molasses is five percent, the rate for electricity must be 13.5 percent.

The project revenues are expected to grow at the general rate. However, this could potentially become an issue at high rates of inflation, which are most likely to be caused by energy prices advancing faster than other prices. On the flip side, the project is less vulnerable to downturns in oil prices.

Although major items of equipment have a long lifespan, the project is well-positioned to capitalize on possible long-term changes in technology and markets. These changes may include variations in the type and volume of fuels available, a molasses shortage in world markets, commercialization of sucrose chemicals, enzyme decomposition of biomass, the use of sugar as a fuel additive or increased demand for ethanol as a motor fuel or turbogenerator fuel.

The project's boiler can burn a wide variety of biomass fuels or, with some modification, coal, either alone or in a mixture with biomass from a 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, for example, could use 50 PSI steam.

As indicated in previous phases, the main thrust of the work 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 for tasks not included in the scope of the study.

The latter includes 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, and preparation of environmental impact statements.

Economic and related work to be carried out in the next phase include the 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.

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Notes to Table 5-3 A, Initial investment includes the following:
1. As put in place
2. Drainage value of mills
3. Mill improvements

4. Power Plant
5. Cumulative average

B. Agricultural operations include:
1. Harvest areas
2. Harvest weight
3. Production costs

C. Transport

E. Industrial operations include:
1, 2. Effective days
3. M21 0 and m expense

Power Plant Operation 1, Output - electricity. Sugar price equals $68 per planted acre. Total column per "valuation of the cane batch Mill in Supplementary Documents." Total column per Table M-6, Section C. Total column per Table P-2. Section D. Assumes mill bought on the first day of Project “lite, other” investment expenditures made at mid year of year indicated. Based on Table A-6, Section 2.0. Based on yields indicated in Section 2.0. Based on the above and Tables A-1 through A-, Section B. Use of working capital equals subtotal x 704 x 10. Training and extension 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. Equals harvest weight x $2.00 per short ton. Per Section D. Per Table M-8, Section C. Equals gross generation per tables P-4 Pos, Section D, x 0.67 cents per kWh. Per tables P-4 and P-5, Section D. Calculated from Table H-5, Section C. About 90% of soluble in, 93% of these are ferment. Most of late, sucrose and 60% of juice is extracted, raw sugar 96% mix.

See Section E. Handling and sales expense equals 6%. Revenues from sales of sugar and molasses: Exclude use of working capital, inflation and taxes to facilitate calculation of internal rates of return, present values, etc. Under varying assumptions about the cost of capital inflation and taxes.

TABLE E-4 LEVELIZED ANNUAL ECONOMIC COST OF PROJECT $000 & Unit cost: Agricultural operation: cane and trash? 7,142 34.5 $13.96 per short ton of whole cane. Grass? 4,410 21.4 $22.14 per ton of grass. Miscellaneous* Subtotal 12,408 60.2. Transportation 2,220 $3.00 per short ton of biomass. Cumulative subtotal 4,628 72.0. Mill and Power Plant 3,487 16.8. Cumulative subtotal 16,115 88.9. Investment charges 2,500 12.1. Total 20,615 100.0.

Notes. 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 value is then multiplied by the.

The corresponding annual capital recovery factor is 5.58 percent, used to obtain the levelized annual economic cost. To calculate the levelized unit cost, the present value of the expenditure's flow is divided by the "present value" of the appropriate flow of physical units, also discounted at seven percent. This includes the rental of land (at $50 per acre) and machinery. It is comprised of a charge for the use of working capital (10 percent per year on 70 percent of production expenditures) and extension expense. It consists only of a seven percent return on and recovery of the initial investment 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.

TABLE 5, LEVELIZED ANNUAL REVENUE REQUIRED

Unit Price Revenues from Sales
Electricity: 10,809, 50.5, 10.09 cents per KWH
Sugar: 1,265, 35.2, 13.34 cents per lb
Molasses: 3,651, 17.7, 49.00 cents per gallon
Handling and sales expense: 7102, a.)
Net revenues: 20,615, 100.0

The total is identical with that in Table E-8. Sugar and molasses revenues are determined as are levelized annual expenditures in Table E-5. Electric revenues are determined by difference. Unit costs are determined as in Table E-1. The unit price of export energy is slightly higher than the highest price shown in Table E-3 because, in Table E-5, working capital is charged separately at 10 percent per year and amortization of the initial investment takes place in 20 years instead of 25. It equals 6.5 percent of revenues from sales of sugar and molasses.

DISTRIBUTION OF ECONOMIC COSTS, PROJECT YEAR EIGHT

Fixed costs:
Agriculture (cane): 2, Grade 37, Subtotal, 0
Transportation: Subtotal, a
Cane Mill: 0, Grade 36
Power Plant: 0.8, Grade 70
Handling and sales: -
Investment charges: 200, Total 50

TABLE E-6 Percent of item total
Variable costs

Specific Joint: 2, 58, 20, 65, 35, 64, 14, 2 + "3, 21, 35, 23, 16, 100" as 'Total' * 200, 100, 100, 100, 100, 100, 100, 100, 100, 100. 'Line Total' as % of 'Project total' = 100. Cost of land and interest on working capital charges included in "Agriculture". "Training and extension" also included in "Agriculture". Interest and amortization of initial investment is also considered. Source: Table E-3, Page 145

TABLE E-7: ROLE OF FEDERAL TRANSFER PAYMENTS TO INDIVIDUALS IN PUERTO RICO'S ECONOMY (CURRENT PRICES)

Fiscal Year: Average Annual 1983-84, 1973-74, Change

$ Millions, § Millions = 4

Transfers to individuals:

Related to production of goods and services in prior years: 1,637, 550, 1.5
Partially related: 186, 17.8
Unrelated: 1,267, 50.7
Not classified: 3,076, 607, 86

Less employee contributions:

Social Security: (337), (67), 9.0
Civil Service Retirement: (48), 0, 8.8
Health & Life Insurance: (2), 0, 3.6

Subtotal: (429), 97, 81

Net: 2,651, 430, 19.9

Personal Income:

Total: 13,386, 6,002, 86
Less non-Federal Transfers: (1991), (406), 93
Net: 12,395, 5,596, 8.3

Ratio: Net Federal transfers to net personal income: 21.4%, 17, 86

Continued Table E-7

Note 1: E.g., Social Security, Pensions
Note 2: Medicaid, all other after deduction of contributions to all forms of social insurance but before income tax.

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 8y 13.

TABLE E-9: WORK FORCE

Fiscal Year Averages: Average Annual 1983-84, 1973-74, Change

Births - number (000): 878
Deaths - number (000): (242)

Net migration - number (000): 246
Population - number (000): 3,270, 2,878, 392
Working-age (H/A) population - 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: 42.1%, 44.3%, (2.2)
Employed - number (000): 742, 744, 0, % W/A population: 32.8%, 38.9%, (6.1)
Unemployed - number (000): 209, 103, 106, 7.3, % W/A population: 9.2, 5, 4.2, % Labor force: 22.0, 12.2, 9.8

Notes: T By differences, Fourteen

"Years or older, 1974: 16 years, 1984. Percentage points: Participation rate, Unemployment rate. Source: Anon, "Informe Económico al Gobernador 1983-84", (Volume 1), Junta de Planificación de Puerto Rico, January 22, 1985, Appendix, tables 22 and 23.

TABLE E-10: STATISTICAL INFORMATION – PUERTO RICO ELECTRIC POWER AUTHORITY

Fiscal year: Average annual 1983-84, 1973-74, change, change (000), (000), (000)

Average sales: 1,159, 2,185, (26), (0.2)

Average generation - KW: 1,402.1, 1,407, -

Peak load - KW: 2,875, 1,823, 52, 0.3

Dependable capacity -KW: 4,207, 3,080, 1,127, 3.2

Peak less installed - KW capacity: 2,292, 1,287, 1,075, 6.4

Notes: All-time high average annual 1983-84 Value change, average sales - Kw: 1,159, 1,322, 1978-79, (2.6)%

Average generation-KW: 1,402, 1,562, 1977-78, (1.8)%

Peak load - KW: 1,875, 2,058, 1978-79, (1.8)%

Percentage points

Source: Puerto Rico Water Resources Authority

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TABLE E-11: A POSSIBLE FUTURE FOR PUERTO RICO

Fiscal year: Average annual 1993-94, 1983-84, change, change (000), (000), (000)

Population-number (000): 3,612, 3,270, 342, 1.08

Working-age (w/a) population - number (000): 2,589, 2,261, 328

Population: 77k, 69.18, 2.6, 3

Labor force - number (000): 2,142, 952, 190

W/A population: 44.18, 42.18, 2.03

Employment - number (000): 1,005, 742,263, 3

W/A population: 32.88, 6.0

Unemployment - number (000): 437, 209, (72)

W/A population: 5.38, 9.28, (3.9)

Labor force: 32.08, 22.08, (10.0)

Manufacturing Employment - number (000): 208, 142, 65, 3.98

Employment: 20.78, 19, 6

Production - index: 162, 100, 62, 4.98

Electricity consumption (million kWh): Manufacturing: 4,574, 3,188, 1,386, 27, Residential: 3,978, 3,474, 508, Other: 4,030, 3,493, 537, Total: 12,582, 10,155, 2,427, 2.2

Continued - Table E-11. Estimated from Anon, "La Población de Puerto Rico para el Año 2000", Junta de Planificación de Puerto Rico, San Juan, 1984, Table 1, and following assumptions of 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. Five percentage points represent the labor-force participation rate. The unemployment rate is also represented. As per the household survey. From Anon. "Informe Económico al Gobernador 1983-84" (Vol. 2), Junta de Planificación de Puerto Rico, San Juan, 25th of September 1985, appendix tables 23 and 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) in million §/KWH

A. Initial investment coal-pier: 82.6, Unit No. 1 (300 MW W/scrubber): 517.3, Unit No. 2: 504.7, Unit No. 3: 1,662. Total: 2,603.9, Capital recovery factor (8) x 13.908 (30yr, 240 months)

Annual investment charge: 223.2 (5 million), Annual net generation (KWH) (3 x 2,038.9 mm) = 6,116.7, Unit cost (cents/KWH): 3,687

Fuel expense unit amount, Delivered cost of coal $/short ton: 56.00, Efficiency KW/short ton = 2,400, unit cost cents KWH: 2.333

Summary: Investment charge cents/KWH: 3.667, Fuel expense cents/KWH: 2.939, Operating and maintenance expense cents/KWH: 0.592, Total cents/KWH: 6.572

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

TABLE E13 LIFE-CYCLE ECONOMIC COST OF A NEW OIL-FIRED ELECTRIC GENERATING STATION IN PUERTO RICO (1984 PRICES)

Summary unit amount: Annual investment charge cents/KWH: 3.599, Fuel expense cents/KWH: 5.662, Operating and maintenance expense cents/KWH: 0.592, Total cents/KWH: 9.793

Note: Assumes 560 KWH per barrel at

$28.00 per barrel of No. 6 fuel oil plus 19.2% "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.

Dighton, "Proposal for the Study of Biomass Commercialization at Sambatache, Arecibo, Puerto Rico". Center for Energy and Environment Research, University of Puerto Rico, Rio Piedras, May 7, 1984, 28 pp.

2. Anon, "Quarterly Economic Review", The Value Line Investment Survey, Arnold Bernhard and Co., New York, May 10, 1985.

3. Anon, "Oil Industry Comparative Appraisals", John S. Herold, Inc., Greenwich (CT), March 1985, pp. B2-84.

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6.0 Conclusions and Recommendations

Several important conclusions can be made about the different areas reported earlier. The agriculture component is feasible because new types of energy grass and cane have been developed for use in Puerto Rico. The agriculture problem is one of reorienting the growers and workers rather than introducing new technology. The important question, though, is whether enough land can be dedicated to this project to ensure 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 restored to 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

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

1. The public sectors of the economy of Puerto Rico will grow fast enough so as to require new electric generating capacity within the next ten years.
2. Sufficient land for the project will be made available from land previously committed to the Rice

Project.
3. 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:

1. The project can contribute substantially to reducing unemployment in the Arecibo area while making an important return on investment.
2. 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.
3. With or without modification, the traditional cane industry in Puerto Rico is no longer viable.
4. 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.
5. In a complex study such as this, it is critical to maintain the momentum and cohesion of the project team.