PN-AAR-719
ISN 39482

Cane Production

for

Sugar and Electric Power

in Jamaica

October, 1984

Sponsored by the

U.S. Agency for International Development
Bureau for Science and Technology
Office of Energy
Bioenergy Systems and Technology Project
Washington, D.C. 20523

and

USAID/Jamaica
Kingston, Jamaica

Cane Production
for
Sugar and Electric Power
in Jamaica

Table of Contents

	Page No.
EXECUTIVE SUMMARY	iv
I. BACKGROUND	1
1. The Jamaican Sugar Industry	1
2. Energy in Sugar Operations	2
3. National Energy and Power Situation	2
4. Execution of the Study	3
II. PROPOSED PROGRAM	4
1. Introduction	4
2. Description of the Pilot Area at Monymusk	5
3. Cane Production	6
3.1 Cane Production Management for Energy and Sugar	6
3.2 Capital Investments Required	6
3.3 Cane Cultivation Practices	7
3.4 Training and Extension	9
3.5 Tropical Grasses	9
3.6 Introduction Plan	9
3.7 Expected Production Levels and Operating Costs	10
4. Mill and Factory Improvements	12
4.1 Description of Monymusk Mill and Factory	12
4.2 Modifications to the Existing Mill and Factory	13
4.3 Costs and Benefits of Mill & Factory Rehabilitation	14
5. Power Plant Description	14
5.1 Fuel Sources	15
5.2 Fuel Handling	18
5.3 The Steam Boiler	20
3.4 The Steam Turbine and Generator	20
3.5 Plant Capital Costs	21

This report is based on the work of a study team sponsored by the A.I.D. Office of Energy through the Bioenergy Systems and Technology Project, USAID/Jamaica, and by the Government of Jamaica through the AGRO 21 Project.

III. FINANCIAL AND ECONOMIC ANALYSIS 22

1. Introduction 22

2. Methodology 23

3. Project Costs 24

4. Financial Analysis 26
   4.1 Benefits 26
   4.2 Internal Rate of Return 27

5. Economic Evaluation 28
   5.1 Employment 28
   5.2 Other Sugar Benefits 28
   5.3 Foreign Exchange 28
   5.4 Economic Value of the Project 28

6. Detailed Analysis of Costs 29
   6.1 Agricultural Field Costs 29
   6.2 Mill Costs 31
   6.3 Land and Mill: Non-Incremental Analysis 32
   6.4 Demonstration Costs 32

7. Financial Requirements & Returns, Non-Incremental Anal. 33

8. Financial and Economic Evaluation of Power Plant 33

IV. TABLES, FIGURES, AND APPENDIXES

Table II-1: Cane Production by Source 10
Table II-2: New/Renovated Equipment for Mill & Factory 13
Table II-3: Mill and Factory Upgrade Costs 14
Table II-4: Power Plant Cost Estimate 21
Table III-1: Investment Required by Monymusk Project: Yrs 1-4 25
Table III-2: Calculation of Price/Kwh Charged to Grid 27
Table III-3: Increased Field Costs Per Acre 29
Table III-4: Calculation of Harvest Labor Costs 30
Table III-5: Average Estate Field Costs: Ratoon Crops 31

Figure II-1: Sources of Cane Production 11
Figure II-2: Schematic Power System Layout 16
Figure II-3: Bagasse Availability as Function of Cane Fiber Content 17
Figure II-4: Fuel Production in Btu's 19
Figure II-5: Annual Oil Displacement 19
Figure A-1: Cane Plant Components A-3

Appendix A: Varieties A-1
Appendix B: Trash Harvesting B-1
Appendix C: Tropical Grasses C-1
Appendix D: Financial & Economic Analysis Tables D-1
Appendix E: Additional Research Needs E-1
Appendix F: Map of Jamaica: Principal Cane Growing Areas and Power Production Areas

CONTRIBUTORS:

Coordinators:	Al Binger (AGRO-21) Alan Jacobs, Director, AID Office of Energy Franklin Tugwell (consultant) Paul Weatherly, AID Office of Energy
Agricultural Analysis:	Teh-Ling Chu (consultant) Maurice Harrison (NSC) George Jackson (consultant) George Samuels (consultant)
Mill and Power Plant Engineering:	Pat Meany (NSC) Robert Miller (JPS) Robert Rollins (consultant) Abu Talib (MITRE Corporation)
Economic Analysis:	Roddy Ashby (PCC) Nigel Grant (MME) Elliott Morss (consultant) Raymond Richman (consultant) Henry Steingass (AID)
Other Contributors:	Frank Ahimaz (AID) Helmut Bourzutchky (SIRI) Norman Dodd (AID) Emile Finlay (SIRI) Jericho Hanson (MME) David Keith (MME) Dean Mahin (editorial consultant) William Rizkallah (NSC) Mike Shaw (SIRI)
Staff:	Sharon Grossett Melannie Hylton Lawson Lennon Lisa Rantallie

Cane Production
for
Sugar and Electric Power
in Jamaica

EXECUTIVE SUMMARY

The principal conclusion of this report is that the Jamaican sugar industry can be made profitable.

Although sugar has been grown in Jamaica for centuries, a combination of circumstances, including declining world sugar prices and a severe shortage of foreign exchange, have undermined the economic viability of the government-owned sugar estates. As a result, they have become a burden to the economy, losing money yearly and requiring significant subsidies.

Over the last decade, experts at the University of Puerto Rico and elsewhere have experimented with new approaches to the cultivation of sugar cane (and other tropical grasses). The results of this research indicate that, with proper management, cane can become a highly attractive source of fuel for the generation of electricity while at the same time producing sugar and molasses.

This study, prepared by a team of experts for the Agency for International Development, analyzes the technical feasibility and economic attractiveness of this new approach as a means of revitalizing the Jamaican sugar industry. The overall conclusion of the study is that Jamaica is in a particularly good position to take advantage of this opportunity.

The pilot program recommended here would be large enough to prove the soundness of the new approach and the magnitude of its potential benefits, among which are large gains in employment in the cane sector, increased production of sugar, large savings in imported oil costs, and the generation of enough electricity to supply a significant fraction of the country's needs.

The pilot project includes the following elements:

- the designation of a pilot project site of approximately 20,000 acres;
- initiation of a cane planting program that will begin with a small area (500 acres) and then expand to include the full 20,000 acres of the pilot site;
- intensive training, utilizing the 500-acre plot, of workers and managers needed to manage the expanded acreage, plus a program of extension services for private farmers;

- the introduction of new agricultural practices that will more than double the tonnages of cane produced;

- the introduction of new harvesting techniques that will recover field trash, which is now burned as a waste product, for storage and use as a boiler fuel;

- retrofit and improvement of the milling facilities at the sugar plant now at the pilot site, so that it is capable of processing 4,500 tons per day of cane;

- design and construction of a high-efficiency power plant rated at 45 megawatts and able to generate a net of approximately 25 megawatts of electricity for the national grid during the grinding season, and up to 45 megawatts during the rest of the year.

An evaluation of the new investment at the pilot site on financial grounds suggests that it is justified, with an internal rate of return of 29.7%. It will begin to produce net foreign exchange benefits by its fifth year and earn (or save, by displacing imports) nearly U.S.$27 million per year by its ninth year. These benefits stem almost equally from the production of sugar and energy, which are the principal co-products of the venture. The project will also provide secure employment for the current labor force and for more than a thousand additional workers. In short, the project will transform a deficit-ridden sugar estate to profitable status, showing an internal rate of return of 10.85%, eliminating the present drain on the government's revenues and foreign exchange reserves.

Evaluated on economic grounds, the project becomes even more attractive, showing an internal rate of return of 39.7%. The economic analysis employs shadow prices for foreign exchange benefits and costs to show the value that additional foreign exchange contributes to the Jamaican economy. It also takes into account employment benefits that the project provides.

Recommendations:

1. That the Government of Jamaica submit this project to potential funding agencies for detailed consideration;

2. That the Government of Jamaica, with the technical assistance of A.I.D., begin a 500-acre pilot plot to adapt and prove new agricultural intensification techniques before going forward with the power plant and cultivation of new acreage;

3. That the Government of Jamaica, with A.I.D., undertake a series of follow-on studies to refine technical and economic parameters.

Cane Production
for
Sugar and Electric Power
in Jamaica

I. BACKGROUND

1. The Jamaican Sugar Industry

When Jamaica's colonial history ended in 1962, the Jamaican sugar industry produced 4.1 million tons of cane, 440,000 tons of sugar, and 100,000 tons of molasses. At that time sugar and molasses were produced in 19 privately owned sugar factories; eleven were owned by Jamaicans and eight were owned by foreign firms. By 1982, the 20th year of independence, cane production had dropped to 2.5 million tons (61% of the 1962 output) and sugar production had declined to 200,000 tons (45% of the 1962 output). The number of sugar factories had dropped to eleven, seven of which were owned by the government.

In many other sugar exporting countries production has dropped during this period as well. This has been caused by competition from new producers, decreased demand during the recession years, and an overall decline in the world market price for sugar. The decline in Jamaica's sugar production, however, has occurred despite favorable export situation for Jamaican sugar. At present Jamaica is exporting about 154,000 long tons of sugar per year under favorable marketing agreements; most of this sugar goes to the European Community, with some 20,000 tons going to the United States. In 1983 the total Jamaican sugar output was below 200,000 long tons. After fulfilling its export quotas, it had to import about 60,000 tons of sugar to meet domestic needs at a cost of about US $15 million. The Jamaican government therefore has a major incentive to expand sugar production.

Jamaica's inability to meet both its export commitments and its own needs with domestic sugar is due primarily to internal factors which have adversely affected cane production and processing. As noted, seven of the sugar factories (including the three largest) are now operated by government corporations; but the government has not been able to invest adequate funds for the maintenance and modernization of mills, nor for field equipment or land management. During most of the decade from 1971 to 1981, farmer cooperatives were responsible for cane production on all of the estate lands associated with the three largest sugar factories (Bernard Lodge, Monymusk, and Frome). The cooperatives did not prove an effective means of managing cane production, which dropped sharply, and were dissolved by the government in 1981.

The entire sugar industry is in need of investment for rehabilitation and modernization. Its problems are many, including poorly maintained irrigation and drainage, inefficient cane production, harvesting and transport, and frequent mill and factory shutdowns. The

industry is currently suffering annual losses in excess of US $20, with accumulated National Sugar Company debt of approximately $75 million. These have resulted in acute funding limitations on needed improvements. Yet the industry continues to play a crucial role in the Jamaica economy -- it is the third leading foreign exchange earner and the second largest employer. Furthermore, the livelihood of 250,000 Jamaicans depends directly or indirectly on the cane industry.

Although Jamaica now has favorable markets for its sugar, there is concern over the longer term market and price prospects in the face of annual worldwide sugar surpluses, recent price pressures, and the political prominence of agricultural subsidy issues in industrialized countries. There is little doubt that the sugar industry will continue to experience losses producing sugar under the present system. Thus it is critical for Jamaica to take steps to address major problems and opportunities in this important sector.

2. Energy in Current Sugar Operations

Bagasse, the remainder of the sugarcane stalk after it has been milled and the juice squeezed out, is generally burned in inefficient low-pressure boilers in Jamaican sugar factories. The low-pressure steam is used (1) to provide mechanical power for cane milling, (2) as process heat in the boiling house, and (3) to generate the electric power needed in the factory. However, due to the inefficiency of mill boilers and turbine/generators operating with low pressure steam, the typical sugar mill does not produce a surplus of electric power and generally must purchase from the utility grid.

Up to the early 1970's Jamaican sugar factories were energy self-sufficient and some factories even had excess bagasse. However, in recent years the supply of bagasse has sharply declined due to reduced cane production.

The lack of a consistent supply of cane to the mills, the inefficiency of the boilers and low-pressure turbine/generators, and the poor operating conditions in the sugar factories have all contributed to increased consumption of fuel oil and of electric power from the grid. By 1982, five million gallons of fuel oil were being used as supplemental fuel in the industry. At one estate for example, most of the 7 MW needed for mill operations is generated at the mill, but nearly 3 additional megawatts are purchased from the grid for the operation of irrigation pumps on estate lands. Under a cane/energy project, a selected complex (including a new power plant) would meet all of its own energy needs and would become a major producer of electric power for the national grid.

3. National Energy and Power Situation

Jamaica depends on imported petroleum for 98% of its total energy needs. Between 1972 and 1981 the cost of the petroleum imports rose from US$71.5 million to US $498 million per year. The percentage of Jamaica's export earnings used for petroleum imports rose in this period from 17.1 to 50.7 percent.

The Jamaica Public Service Company (JPS), the national electric utility, generates 95 percent of its power with imported fuel oil. The 3.1 million barrels of oil used for electric power generation in 1983 cost over US $93 million. Electricity demand in Jamaica has grown from 826 Gigawatthours (Gwh) in 1971 to 1172 Gwh in 1983. Despite decreasing overall demand for petroleum (3.4 percent per annum, 1980-1983), electricity demand continues to increase at an annual rate of nearly 5 percent. Large rate increases arising from the removal of subsidies and the recent devaluation of the Jamaican dollar are expected to reduce the growth of demand in 1984 and the near future.

Nevertheless, present power supply is considered inadequate and unreliable. Current installed capacity is approximately 450 Mw, but available capacity varies from 200 to 350 Mw due to the poor condition of many generating units. With peak demands of 220 to 240 Mw, available capacity is often strained and breakdowns are frequent. Furthermore, many peaking units burn diesel, costing 25 percent more than fuel oil. Therefore, a significant expansion in generating capacity to meet Jamaica's power needs is planned for the coming decade, and adding capacity based on Jamaican bagasse resources represents a cost-effective option in comparison to new oil or diesel-fired units.

4. Execution of the Study.

At the request of the Government of Jamaica, the US Agency for International Development provided a team of technical specialists during the period May - August 1984 to evaluate the technical feasibility and economic attractiveness of the generation of electrical energy and sugar from increased cane production in Janamica. These specialists worked with assessment groups, composed of GOJ individuals from relevant ministries and organizations, in evaluating program options in three areas: agriculture/field, mill and power plant, and economic analysis. This team concludes that the sugar industry of Jamaica can be turned around with the institution of a "cane/energy" system. This team further concludes that a prototype cane/energy system can be established at an existing sugar estate.

The following section presents a description of the proposed cane/energy program, detailing agriculture/field activities, proposed mill renovations, and the plan for a bagasse-fired power plant. This section is followed by the financial and economic analysis, and then the Appendices.

II. PROPOSED PROGRAM

1. Introduction

Cane/Energy is a name given to a specific set of system concepts and practices which can be described as follows:

- selection of sugar cane varieties capable of high biomass production;
- intensive cultivation to obtain significantly greater cane yields per acre;
- efficient use of milled bagasse as a boiler fuel;
- collection and preparation of cane field "trash" as a supplemental boiler fuel;
- year-round operation of a high-efficiency power plant utilizing primarily cane-derived fuel to supply steam for sugar factory operations as well as baseload power for the Jamaica electric grid.

The cane/energy approach to new cane production is particularly appropriate for Jamaica. It attempts to take maximum advantage of the country's known agricultural resource capabilities in an important industry. A successful cane/energy development program would offer a number of important benefits to Jamaica:

- provide less expensive energy and displace substantial oil imports used for power generation, now totaling 3.1 million barrels per year at a cost of US$93 million, thereby helping to alleviate the foreign exchange crisis by reducing hard currency expenditures;
- produce sufficient additional sugar to displace imports, now totaling 60,000 tons per year at a cost of US$15 million; and
- establish a basis for revitalizing the sugar industry, thereby maintaining and potentially increasing employment.

Perhaps most important, the diversification of the sugar industry into provision of baseload electricity also provides a measure of protection against two of Jamaica's most prominent vulnerabilities of recent years -- destabilizing fluctuations in the world sugar market, and increasing world prices for imported energy. Together these two factors have accounted for a significant portion of the country's balance of payments problems over the past ten years.

The team concentrated their work on an analysis of the feasibility of developing a complete cane/energy system at a pilot estate. After an assessment of possible sugar plantation/factory candidates, Monymusk

(Clarendon Sugar Co., Ltd.) was selected as the site for evaluation of all technical parameters. The assessment is designed as a case study. The findings should be considered applicable to other sugar operations, especially those at a similar scale, with necessary adjustments for site-specific factors (e.g., condition of the plantations and mill, rainfall/irrigation needs). (As a rough indication, the map in Appendix F shows cane growing areas of Jamaica and their potential electricity output under a cane/energy management approach.)

2. Description of the Pilot Area at Monymusk

The Monymusk Estate and surrounding private farms which produce cane together comprise an area of about 20,000 acres on the Clarendon Plain on the south coast of Jamaica. Three other sites were considered for the project: namely, Frome, Bernard Lodge, and Duckenfield. The Monymusk Estate was chosen as the most suitable site for the pilot project in relation to acreage, water supply, soils, and topography, although it presents challenges related to the quantity and quality of water supply and salinization not present at the other sites. The Monymusk Estate and Sugar Factory is now operated by the Clarendon Sugar Co., Ltd., a subsidiary of the state-owned National Sugar Company.

About 12,000 acres of estate lands are available for the project. The project will also draw cane from about 4,000 acres of larger farms, ranging from 30 to 1,000 acres per farm, and about 4000 acres of small farmer holdings. The major finding of this assessment is that the introduction of a cane/energy system at Monymusk is a technically feasible and economically attracive proposal.

The mean temperatures in this region are 80°F (27°C) in the warmer months and 70°F (21°C) in the colder months. These are excellent temperatures for maximizing cane production. Over a 30 year period the mean annual rainfall has been 36.2 inches, with the heaviest precipitation concentrated in a May-June rainy period and in a season of heavier rains in September and October; it is not possible to harvest cane during these rainy seasons. Except for the fall rainy season, there is a water deficit in the area and irrigation is necessary for good crop production during nine to ten months a year. The Monymusk Estate lands are irrigated with ground water from about 100 wells ranging in depth from 70 to 200 feet.

The estate and its surrounding area is located on the low alluvial plain of the Rio Minho River. About 85% of the area is aqualeta clay soil, a deep, imperfectly drained soil with high moisture capacity and slight erosion hazard. Special management problems are drainage and inadequate moisture supply in the dry season. In the absence of good drainage, the aqualeta clay soil tends to show high accumulation of salts from the saline ground waters. About 2,000 acres of the Monymusk Estate lands must be considered sufficiently saline to impair productivity. This problem can be alleviated through careful attention to drainage and proper irrigation techniques and, where necessary, light applications of gypsum (calcium sulfate) to prevent soil alkalinization.

3. Cane Production

This section of the report describes the agricultural components of the cane/energy system as it would be implemented at the Monymusk Estate. The approach is based on a thorough evaluation of the steps needed to grow high tonnages of cane under Jamaican conditions and deliver the cane and cane residues to the factory and powerplant.

3.1 Cane Production Management for Energy and Sugar

The agricultural objective is to maximize yields of biomass (plant matter) rather than just sugar, as has been the case in the past. The biomass is then used as a fuel to produce electricity. In effect, sugar and biomass fiber become co-products, each contributing to the economic viability of the system. This new objective requires changes in agricultural techniques extending throughout the crop cycle, beginning with soil preparation and extending through harvesting.

The net effect of this approach is to increase dramatically the tons of cane produced per acre. It is estimated that production will eventually reach 65 long tons per acre, almost three times the current average of about 23 long tons per acre. The total sugar produced per acre also increases, even though the quantity of sugar per ton of cane declines slightly. Costs of production also rise but the costs per ton of cane decrease. Because there is less sugar per ton of cane, the costs of sugar per ton increase. The loss of sugar per ton of cane, however, is more than compensated by gains from energy sales.

3.2 Capital Investments Required

A number of investments in agricultural machinery, irrigation systems, equipment, and land preparation are necessary to implement the new approach to cane management at Monymusk. These investments are described below, and the cost figures are detailed in Section III: Financial and Economic Analysis.

Irrigation. Ample water throughout the year is essential to achieve high tonnages of cane, and investments are needed to improve the water supply system at Monymusk Estates. In the Clarendon area rainfall is not sufficient to meet agricultural demand, except during the rainy seasons in spring and early fall when surface runoff in the nearby mountains keeps the rivers and streams well supplied with water which can be used for irrigation. Monymusk therefore depends heavily on water pumped from limestone aquifers which is recharged during the rainy season. Lack of parts and inadequate maintenance have led to a deterioration of the pumping stations and irrigation canals.

The investment required to develop water resources and improve the irrigation system is being reviewed as part of a larger analysis of water resource options in the Clarendon area. The findings will make possible a more precise estimate of the capital required, but for the purposes of this study we have used an estimate based on a study prepared by the management of the estate.

Drainage. Soil salinity is a major problem in the Clarendon plains, and has been worsened by several years of abnormally low rainfall. The aqualeta clay soil, because of its texture, tends to show higher accumulations of salts if proper drainage is not in place. The salt content of ground waters has been growing and salinity in the soil increases with depth. In most areas soil salinity is relatively low in the upper layers of but may reach toxic levels at 4.5-6 feet. If the soils are irrigated with poor quality water, or if the drainage system is impaired, salinity could become a serious problem for agricultural productivity even on lands not presently experiencing difficulty. As pointed out previously, of the 12,000 acres of estate land selected at Monymusk Estates for this project, about 2,000 must be considered sufficiently saline as to have impaired productivity. On these and other growing areas, land shaping and forming will, as part of the improved irrigation system, also help in reducing the salinity of the soils by encouraging the leaching of accumulated salts by storm rains.

Field Equipment and Machinery. The new cane management methods will require investments in new equipment as well as expenditures to improve the stock of existing equipment, much of which is old and worn from constant use. New equipment includes: rotovators for better conditioning of the soil, fork lifts, rotary scythes for cutting the tropical grass and hay rakes for baling the cane trash and tropical grasses.

3.3 Cane Cultivation Practices

As noted, the management of sugar cane to maximize biomass production differs from the traditional approach. Key aspects of this new approach are described below.

Soil Preparation. Soil preparation is especially important in attaining higher tonnages of cane, since it is essential in promoting the development of a large healthy root system. This means deeper plowing, including subsoiling, to break up any soil compaction and aid in aeration and internal drainage of the heavy clays. Land smoothing is also needed to eliminate any depressions which may cause water and salt accumulation. A new technique to be introduced is the use of the rotovator. This machine is used with a tractor after the last harrowing to ensure good soil tilth, and a proper seed bed.

Fertilization. In traditional practice fertilizer is applied in various formula and at various rates, usually about 12 weeks after

planting or harvesting, on the soil surface between the rows, and then covered. Under the new methods fertilization will occur in two phases; one beneath the seed bed prior to planting and the other applied on the surface about 12 to 14 weeks after planting. Ratoon crops will also receive two applications of fertilizer; one following harvesting and the other 10 - 12 weeks later. Fertilizer rates and formulations will be developed from soil and foliar analysis but it is anticipated that there will be a significant increase (approximately 100%) in the level of nitrogen added.

Planting. Sugar cane is planted from immature cane stalks (6-8 months old) called seed cane. Planting will be done at the regular times i.e. spring and fall. However, the distance between rows will be increased as will the density of planted material in the rows. In this system of planting, between four and five tons of seed cane is planted per acre.

Irrigation. At present, seven irrigation wettings are applied to the soils. To achieve higher tonnages, more water will be applied and irrigation will not be withheld for a few months before harvest to "ripen" the cane, as in the current practice. Between eleven and thirteen wettings will be applied at three-week intervals for heavy clays, with more frequent applications for lighter soils.

Herbicide Application. A pre-emergence application of herbicide will be used to control weeds before germination, followed by a post-emergence application. Once the canopy has closed sunlight is cut off and no additional herbicides are necessary.

Harvest. Cane will be harvested by hand as it currently is in Jamaica. However, the cane will no longer be burned prior to harvest. This will make it possible to collect the resulting trash (tops and leaves), but will require higher pay for manual laborers who do the cutting. Cut cane is loaded and transported to the mill by machines. Trash on the ground will be solar dried for four or five days, then raked, baled and transported to the mill area where it will be stored. (See Appendix B: Trash Harvesting, for further details). The trash remaining after baling will be left on the field to provide mulch and help control erosion.

Labor needs. Because production from the same lands will be nearly three times greater than it is currently, and because unburnt cane will require more time, per ton, to harvest (reflected in higher wages), the cane energy system will increase employment significantly. Harvesting will employ more than triple the current levels of labor (measured in person months). However, because the grinding season is longer, we etimate the total number of workers at between two and two-and-one-half tne number currently employed.

New Varieties. Higher productivity will be achieved by the phased introduction of new varieties whose genetic attributes result in the production of large amounts of biomass. The varieties chosen may be adjusted according to the value of the fiber for combustion as well as the market for sugar. Several Jamaican commercial varieties have been identified by team experts which appear to have the capacity to produce high tonnages, and these will be used until new foreign varieties, such as those already tested in Puerto Rico and Louisiana can be introduced. For further information on Jamaican varieties, see Appendix A: Varieties.

3.4 Training and Extension.

The new agricultural practices make it necessary to pay careful attention to training and information dissemination. Training will begin with the first 500-acre plot (described below), which will serve as a center for demonstrating new practices. The personnel trained on the pilot project will form a cadre to assist in further training. Operators of the large private farms will also require assistance, and their personnel are expected to participate in the pilot plot. Finally, extension services will be necessary to disseminate information and train operators of the small farms whose production is part of the project. Therefore, two qualified experts will be needed immediately, one for the pilot plot, the other to work with the large farmers. In addition, by the second or third year, three or four extension personnel will be needed to begin working with the small farmers, providing instruction, seed and other materials to help them raise their production levels.

3.5 Tropical Grasses

Tropical grasses may be used as a supplemental fuel, and the assessment includes a brief review of the methods to be used in growing them. Details are presented in Appendix C. The pilot plot of 500 acres may include at least 50 acres of Napier grass (genus Pennisetum). Grass is grown with one plant crop and five ratoons, and is harvested at six month intervals. Other grasses, notably Sordan (a hybrid of Sorghum and Sudan grasses) should also be evaluated for its performance under Jamaican conditions.

3.6 Introduction Plan

The project will seek confirmation, via a 500 acre pilot plot, of the accuracy of estimates of the agricultural inputs necessary to achieve target yields under Jamaican conditions, as well as an assessment of several varieties of Jamaican sugar cane (and, perhaps, grass) for their biomass potential and sugar content. This activity is scheduled to begin in early 1985, and will allow the training necessary for the subsequent expansion of land cultivated in the new cane production system. Mill and factory improvements will begin at the completion of the 1985 crop, so that by the third year the mill will be able to receive the higher tonnages produced. Imported varieties must be tested for smut and rust disease, then go through Jamaican quarantine, and multiply in seed plots. It is expected that these varieties can be introduced in the third or fourth year of the project.

3.7 Expected Production Levels and Operating Costs

Expected Production Levels. The products obtained from the agricultural component of the cane production system, when the millable cane has been processed and when the trash and grasses have been harvested, are: 1) bagasse, 2) baled trash and grasses, 3) sugar, and 4) molasses.

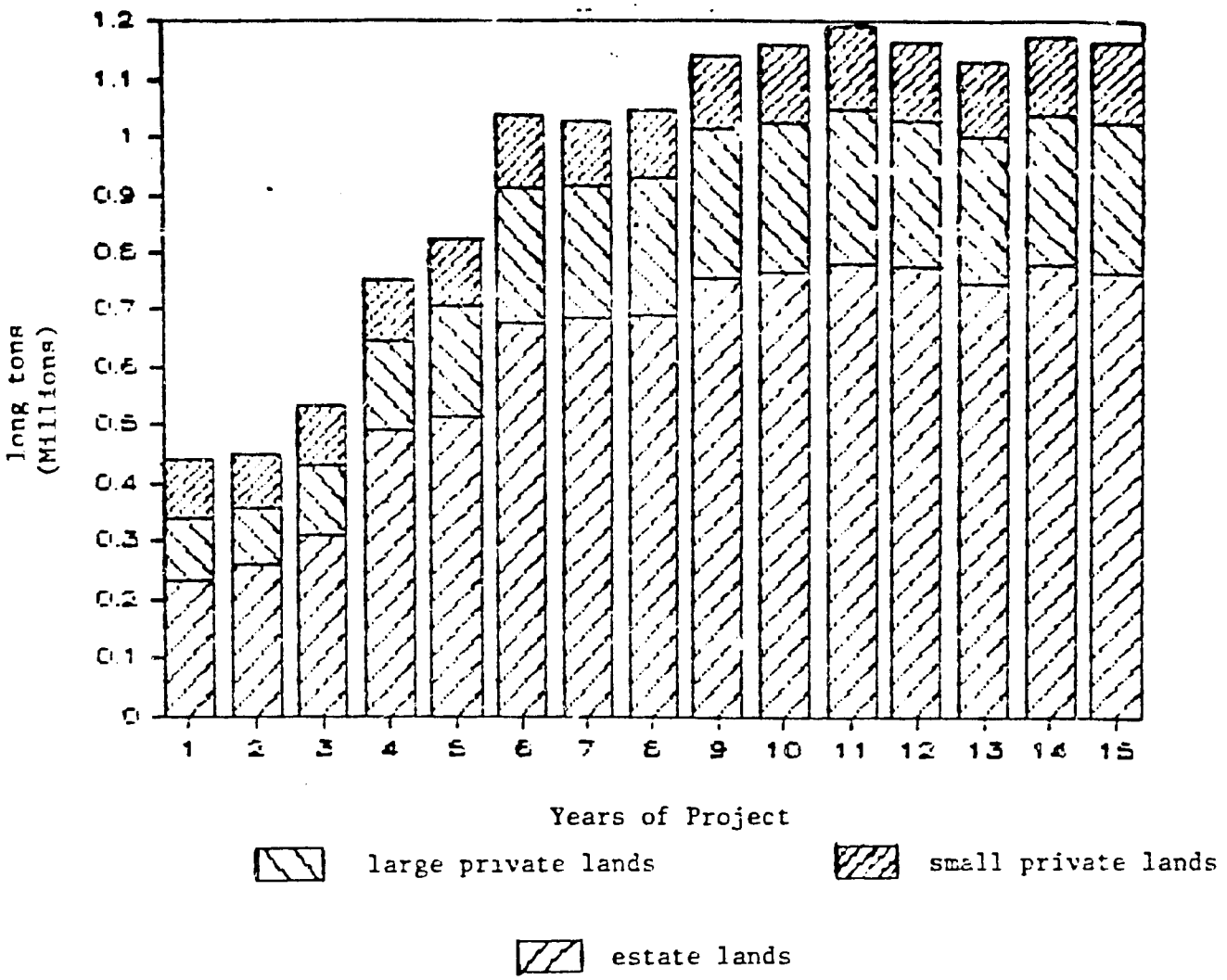
Following the introduction of the new cane production system, cane yields will increase from approximately 23 long tons/acre (current levels) to 50 tons/acre on the estate and large private farms. The increase in cane yields expected by source and by year is shown in Table II-1, Cane Production by Source, and graphically depicted in Figure II-1, Sources of Cane Production. Small farms are expected to lag behind in the adoption of new practices for various reasons. As indicated above it is anticipated that new varieties will be introduced between the third and fourth years. By year ten, all acreage of estate and large private farms will be producing new varieties and experiencing additional yield increases of approximately 30%, averaging 65 long tons/acre. By the same year it is estimated that small farm yields will also begin to increase as a result of new cultivation techniques and the introduction of new varieties. Accordingly they will be producing an estimated 35 tons/acre. By year ten, in other words, new management and varieties will have been fully introduced and the new cane production system will be in place.

TABLE II-1: Cane Production by Source

Year	Total Estate Production	Total Large Farm Production	Total Small Farm Production	Grand Total
1985	232,884	105,283	105,283	443,451
1986	257,228	97,932	97,932	453,091
1987	309,601	122,185	101,185	532,970
1988	494,249	151,506	108,506	754,261
1989	514,792	192,861	114,111	821,764
1990	677,400	237,250	123,000	1,037,650
1991	690,000	225,500	115,000	1,030,500
1992	693,550	236,500	118,750	1,048,800
1993	758,600	256,500	127,250	1,143,350
1994	766,000	259,750	133,750	1,159,500
1995	783,000	266,500	143,500	1,193,000
1996	776,250	253,350	134,750	1,164,250
1997	749,750	250,000	133,000	1,132,750
1998	783,000	256,500	136,500	1,176,000
1999	766,000	250,750	138,250	1,164,000
2000	786,500	266,500	143,500	1,196,500

FIGURE II-1:

Sources of Cane Production



Bagasse yields will vary (as will sugar yields) with the amount of fiber in the selected cane variety. Varieties range from approximately 15 percent fiber (current Jamaican levels) to as much as 21 percent. Four tons of millable cane stalks, cut by hand, produce approximately one ton of cane trash (45% tops, 15% attached leaves, 40% detached leaves-- (see Figure A-1, Appendix) and of this, it is estimated that sixty percent will be collected for use. Although research suggests that yields of 32 long tons of dry biomass per acre can be obtained from grasses grown under Jamaican conditions, the conservative figure of 20 dry tons is used for present purposes.

The sugar content of canes grown for energy is lower than canes grown by conventional methods. This is due partly to the agricultural management method, which is designed to promote growth rather than sugar accumulation. Although conventional canes can contain as much as 12 to 13 percent sugar, an average sucrose production of 8 percent, or one ton

of sugar for each 12.5 tons of cane is used. Molasses, the material remaining after the sugar has been extracted, will average 5.5 gallons per ton of cane.

Cost Estimates. Present estimates for the costs of agricultural operations are presented in the Section III: Financial and Economic Analysis. Estimates have been derived, whenever possible, from the costs of similar operations in Jamaica, with appropriate adjustments for increased costs stemming from new management methods.

4. Mill and Factory Improvements

This section of the report presents the technical and economic considerations associated with retrofitting an existing mill and factory to process cane efficiently so as to produce high quality utility fuel and sugar as co-products. Although this report describes necessary modifications for a specific mill, the Clarendon Sugar Company, Ltd., Monymusk Cane Sugar Factory, the results of this assessment are largely applicable to the other two large mills (i.e., Frome and Bernard Lodge) owned by the Jamaican government.

4.1 Description of Monymusk Mill and Factory

The Monymusk Cane Sugar Factory was originally designed to process 225 long tons/hour or 5400 long tons of cane per 24-hour day when it began operation on April 6, 1949. Today's average cane processing rate (1984 actual average) is 2100 long tons per day, or 39 percent of design capability. The reasons for this drastic reduction are 1) a decline in cane deliveries from estate lands, from 300,000 tons ten years ago to 192,000 tons this year (Monymusk also received 201,000 tons this year from private lands); and 2) inadequate cane yard facilities.

Cane is prepared for the mill by washing and size reduction, through two sets of knives in series. The one set is turbine driven, requiring 37,000 lbs/hour of steam at 200 psi - 525°F, and the other electric motor driven.

The mill consists of two turbine drivers, each driving three sets of rolls in series. The bagasse moisture content is always over 50 percent (54.18%, May 29, 1984), an indication of worn mill roller surfaces. The two turbines operate simultaneously and require 90,000 lbs/hour of steam at 200 psi - 525°F.

The boiling house, where the water content of the cane juice is reduced by evaporation and the sugar crystallized in vacuum pans, operates on 25 psi exhaust steam (127,000 lbs/hr) from the above-mentioned turbines and approximately 50,000 lbs/hr of 25 psi steam extracted from the main electric-power turbine. Eighty-five percent of this steam is recoverable as condensate (108,000 lbs/hr) and returned to the boiler feedwater system for the power plant steam generator.

The condition of power-house equipment and associated auxilaries is not presented here since they will be replaced in the modified mill discussed below. The equipment includes: existing steam boilers,

turbine generator, cooling water and boiler feedwater system, and bagasse handling system.

All mechanical equipment and factory buildings need repair. As noted, over a period of years sufficient funds for annual maintenance during the off-harvesting season have not been made available. In recent years, the funds available have been barely adequate to pay a limited maintenance work force during the non-grinding season, and have beeninadequate for sufficient spare parts or factory upgrading.

4.2 Modifications to the Existing Mill and Factory

The project will modify the mill to increase its capacity to 4500 long tons/day of cane to produce sugar, molasses, and electric power. The modifications to the mill involve both replacement and retrofit of existing equipment, buildings, and structures. The existing boilers in the mill and factory will be removed and steam and electricity necessary for operations will be drawn directly from the new power plant.

Table II-2: New/Renovated Equipment Recommended for Mill and Factory

Cane Yard: New Equipment
- 1 each Gantry structure with 2-20 gantry cranes equipped with 8 ton grabs,
- 2 each 2084 off loaders, one (1) mobile, one (1) fixed,
- 2 each 45° Washing Plants,
- 1 each 966 Cat. Wheel Loader.

Cane Yard: Equipment Renovations
- resurface the entire cane yard with reinforced concrete
- raise the entire feeder carrier and the tail end of the main carrier above ground
- modify the existing feeder tables to span the width of the new gantry, and to include the two (2) new wash plants.

Mill: New/Replaced Equipment
- belt-type tramp iron separator added to the cane feed line,
- six (6) new pumps (2 screened and 4 unscreened)
- three (3) new mill and eighteen (18) reshelled mill rollers
- gears for first reduction of No. 2 drive unit
- pinions and coupling boxes

Boiler House: New Equipment (Most already on site, but not installed due to lack of funds)
- install the new Oliver filter (at site)
- install the two (2) new seed receivers (at site)
- install the two (2) new evaporator vessels (at site)
- install one (1) new vacuum pan (at site)
- replace valves
- replace vacuum pumps, ten (10) total
- replace/repair lagging, as required

In order to sustain the expected crushing rate of 4500 long tons/day on a continuous basis, a major equipment rehabilitation program should be undertaken. A major barrier to efficient operation of the Monymusk factory is the cane receiving yard. The existing cranes are under-rated for the weight of cane delivered in any single truckload. The study team recommends that the cane yard area be re-designed.

Some of the retrofit or upgrading requirements, as observed during the factory visit in July 1984, are summarized in Table II-2. In addition to the above specific areas, general repairs are required throughout the factory. Only minimum work should be performed in the steam electric power generating areas as this will be retired.

4.3 Costs and Benefits of Mill and Factory Rehabilitation

The study team assembled preliminary estimates of the costs of mill and factory up-grading. The costs, shown in Table II-3, were estimated by Monymusk personnel from return cost data and experience on-site, and should represent an accuracy of +/- 10%. Once these modifications have been completed, production capacity would be maintained through an annual factory maintenance program costing an estimated J$6,000,000 per year.

TABLE II-3: Mill and Factory Up-Grade Costs

	US$ X 1000	J$ X 1000
Cane Yard	1,500	4,500
Milling Plant	810	1,500
Boiling House	225	2,090
Sub Total	2,535	8,090
General Repair - 1984/85 Budget		9,650
Factory Total	US $2,535	J$ 17,740

Most of the modifications of the mill and factory outlined above will be carried out during the first three years of the project, prior to the completion of the power plant. Steam extracted from the turbine of the new power plant will be used in the sugar factory to operate the turbines in the milling department and to evaporate sugar in the boiling house. The elimination of the regular operation of the suspension boiler in the sugar factory will save an average of about 2.4 million gallons of fuel oil which has been burned to supplement the energy produced from bagasse. The factory's three present turbine-generators and the present bagasse handling system will be deactivated.

5. Power Plant Description

The new power plant will be designed and operated as an efficient high-pressure utility power plant with an expected onstream factor of 98.6 percent. The power plant will be constructed alongside the Monymusk sugar factory in order to use bagasse as the primary power plant fuel

during the approximately 240 days/year of factory operation. The plant will provide electric power to the Jamaica Public Service utility grid. It will also provide all the steam, electricity, and process water needed by the factory during the period of factory operations. Recoverable condensate will be returned to the power plant from the factory.

The major components of the power plant are:

- a steam boiler capable of producing up to 450,000 lbs/hour of high pressure steam
- an extraction turbine connected to a 45 Mw electric generator.
- a water treating facility,
- boiler feed water equipment,
- a cooling tower,
- fuel handling equipment,
- ash handling equipment,
- an electric power transformer station.

The layout of the total system is depicted in Figure II-2.

5.1 Fuel Sources

The primary fuel for the proposed power plant during the cane-crushing season will be bagasse available from the modified factory. A 240-day crushing season is assumed for this study. It is expected that the normal crushing rate at the factory will be at the rate of 4500 long tons/day or 187.5 long tons/hr.

The amount of bagasse available for the power plant during the crushing season is dependent on the fiber content of the cane. The normal cane cultivated in Jamaica contains approximately 15 percent fiber. However, the cane produced after the introduction of new varieties may have a fiber content greater than 15 pecent. The relationship between fiber content and energy output is illustrated in Figure II-3.

As shown in the figure, as the fiber content of cane increases from 15 percent to 21 percent, the amount of bagasse, at 35 percent moisture, available for the power plant will increase from about 44 long tons/hr to about 60 long tons/hr. This bagasse will contain approximately 11.5 million Btu per metric ton. At 35 percent moisture content, the bagasse fuel can sustain a boiler firing rate of about 500 million Btu per hour, whereas at 21 percent fiber content, the firing rate will be about 699 million Btu per hour.

The study team estimated that, during the off-season, the cane trash (cane tops and leaves), which is harvested, will be of sufficient quantity to provide the main source of fuel. The cane trash will be baled and stored for use during the off-season. A normal 52-day

Figure II-2: Schematic System Layout

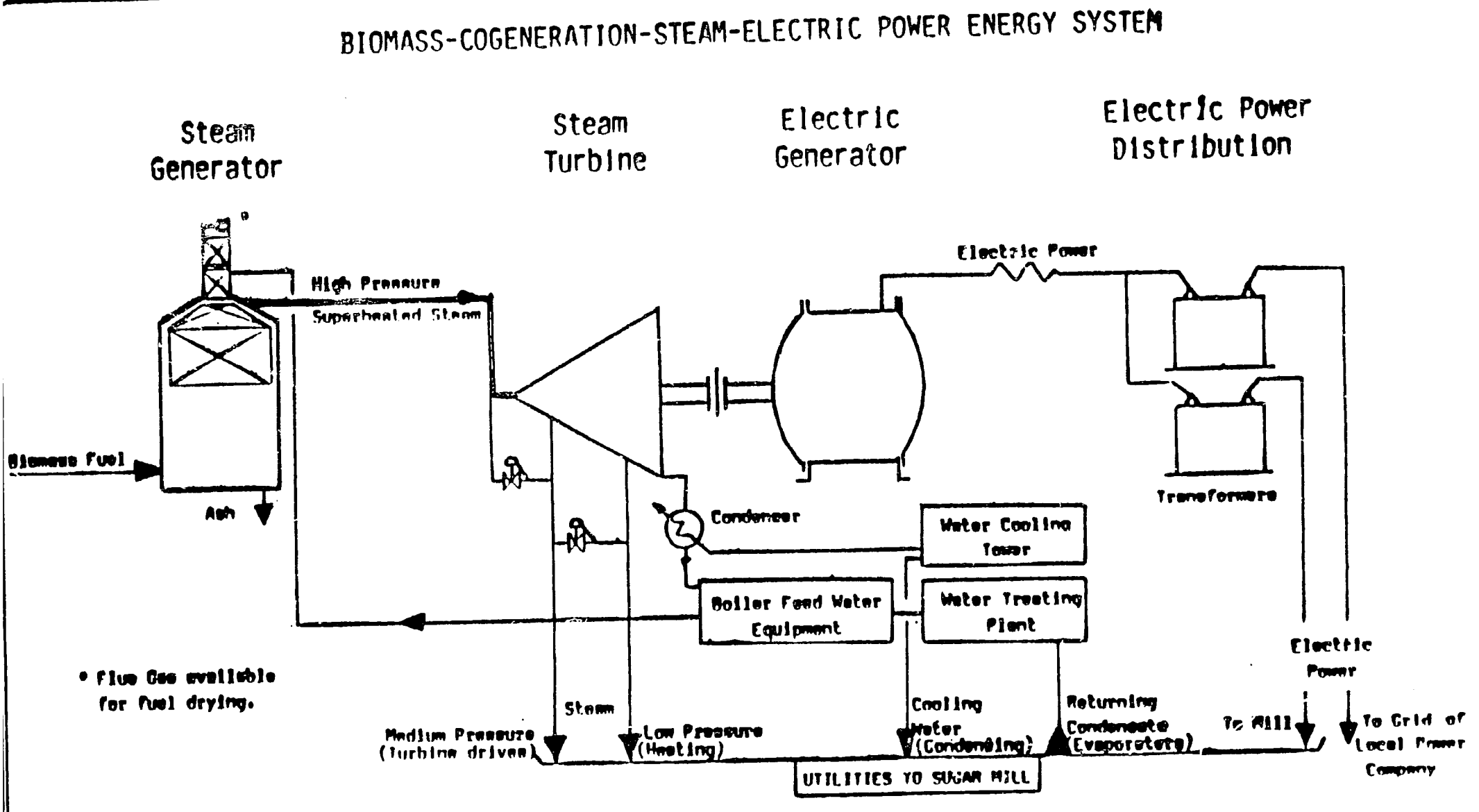
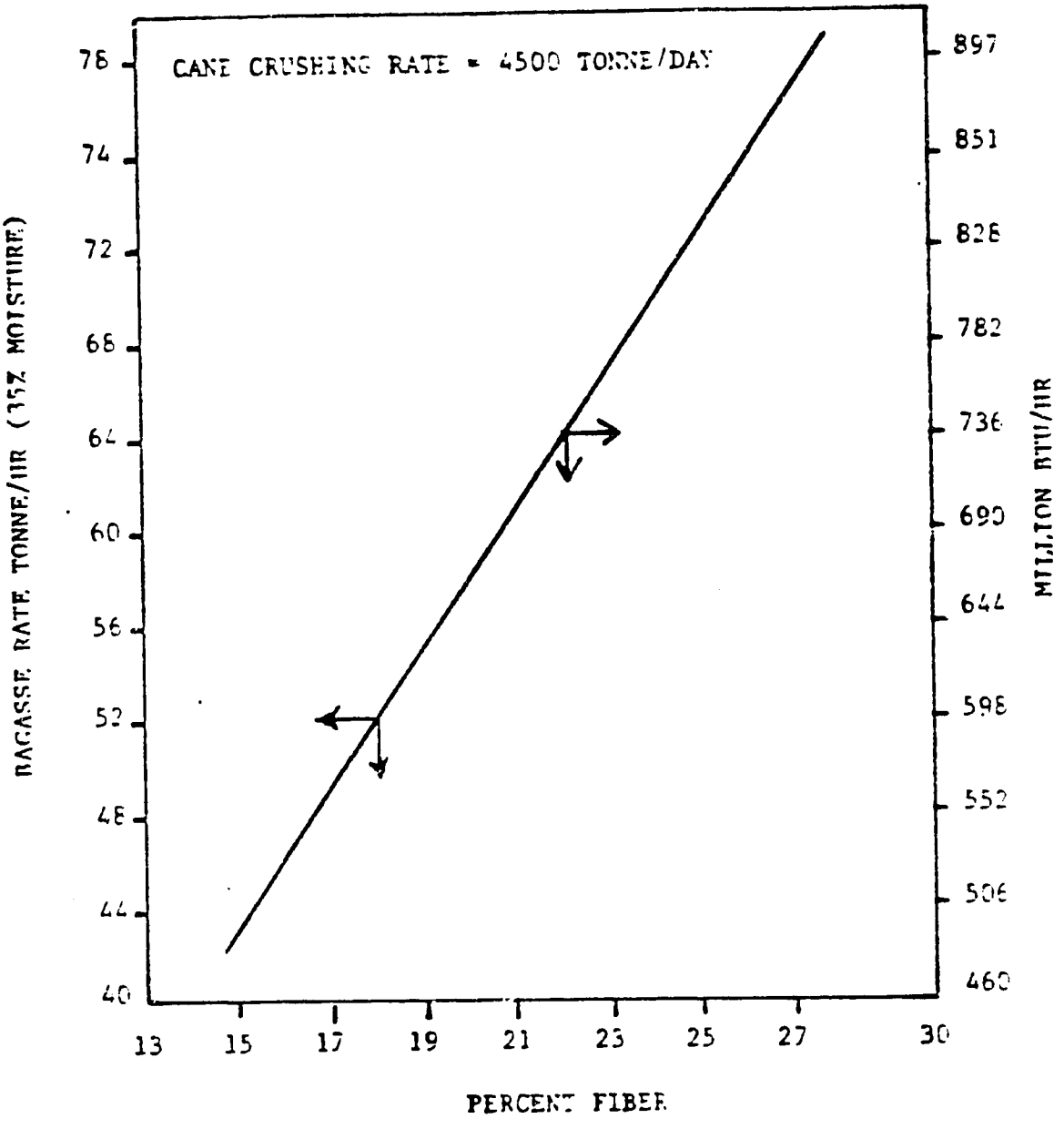


Figure II-3:
Bagasse Availability as Function of Cane Fiber Content



off-season is assumed for this study. The bales retrieved during the off-season must be broken up and the trash reduced in size to compare with the bagasse (2 inches long, 1/2 inch wide, 1/16 inch thick maximum size, passing an 80 mesh/inch screen). The study team has recommended the purchase of a shredder and a hammer mill to prepare the trash as boiler fuel. This equipment permits the use of other fuels such as wood, coal, or other forms of biomass.

It is estimated that 75,000 long tons of trash per season can be baled and stored for use during the mill's off-season or during the cane crushing season as a supplement to bagasse. The baled material is expected to have a moisture content of about 20 percent, with a corresponding energy content of about 14.8 million Btu per long ton.

The total bagasse and cane trash fuel projected over the course of the project, in Btus, is shown in Figure II-4. The estimates are based on the cane agricultural program described in Section 3 of this chapter. The annual oil displacement projected from using this fuel in the power plant, which begins operation in Year 5 of the project, is shown in Figure II-5. In actuality, some oil will be displaced in Years 1-4 as well, as the mill is able to use the increased bagasse yields in its existing steam power facilities. This benefit is taken into account in the financial and economic analysis.

5.2 Fuel Handling

The study team recommends that bagasse and supplemental fuels be received, stored, and prepared as follows:

The 50 percent moisture bagasse from the mill may be fed either directly to the steam generator fuel preparation equipment or to storage. Since standard mill practice is to shut down for one to two hours daily, and for 12 hours every Sunday, there must be a capacity to store bagasse to allow continuous operation of the power plant.

Bagasse should be delivered to a bagasse storage building via an overhead conveyor, and recovered for delivery to the power plant by means of an underground conveyor. The bagasse storage capacity should be sufficient for five days operation.

On the other hand field trash can be stored in bales in the field and delivered to the power plant only as required by the overall, mixed-fuel, consumption schedule. Bales will be stored directly outside of the fuel preparation building and delivered to the fuel preparation equipment by conveyor. Alternate fuels may be handled similarly to the trash fuel.

The bagasse fuel contains 50 percent moisture as received from the mill and will be dried to 35 percent moisture content before entering the boiler as fuel feed system. The trash contains 20 percent moisture and needs only shredding before entering the fuel system. Both milled bagasse and trash are to be passed through a hammer mill-dryer-fuel preparation unit immediately prior to entering the boiler fuel feed system. This unit includes cyclones to separate the fine fuel particles from the vapors after the drying operation. All conveying equipment would be totally enclosed to contain dust.

Figure II-4: Fuel Production in BTU's

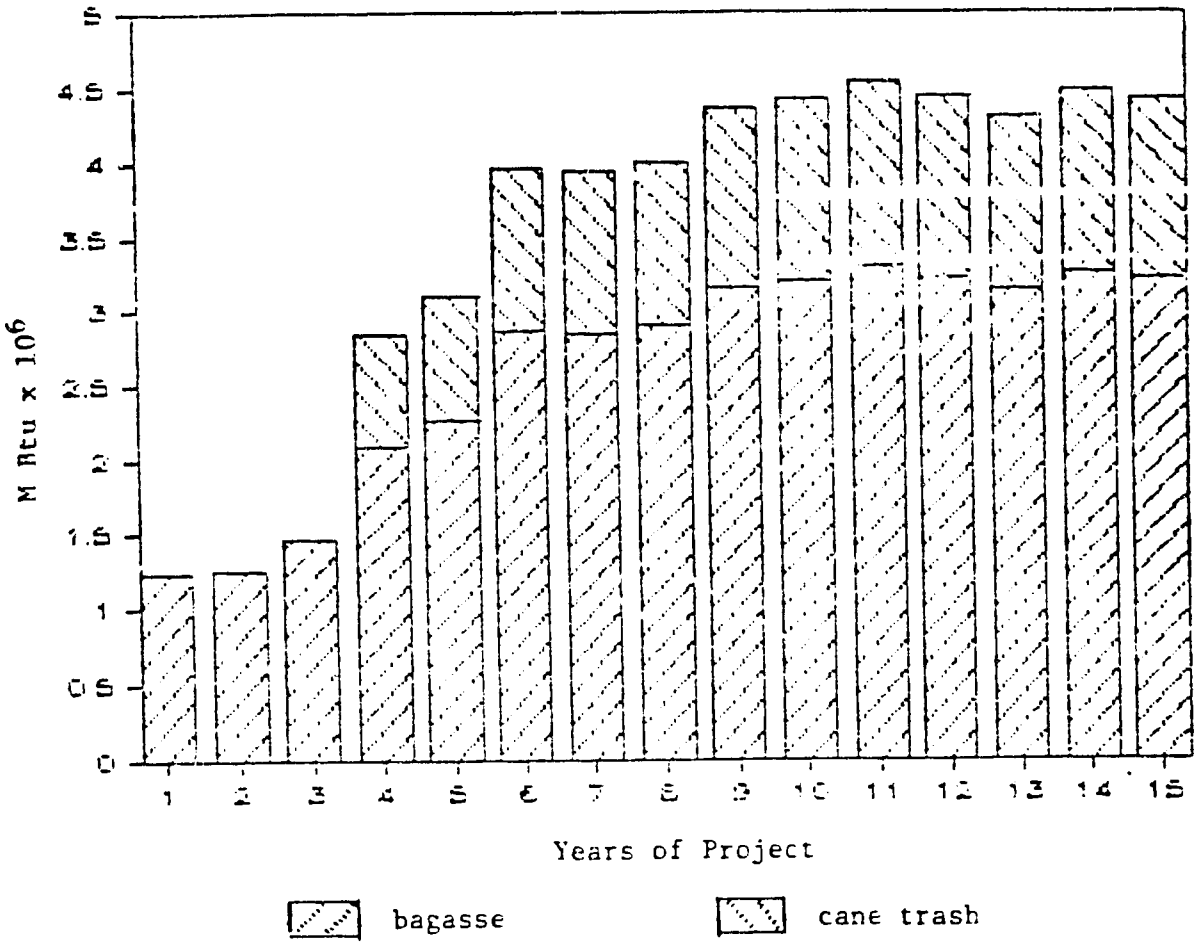
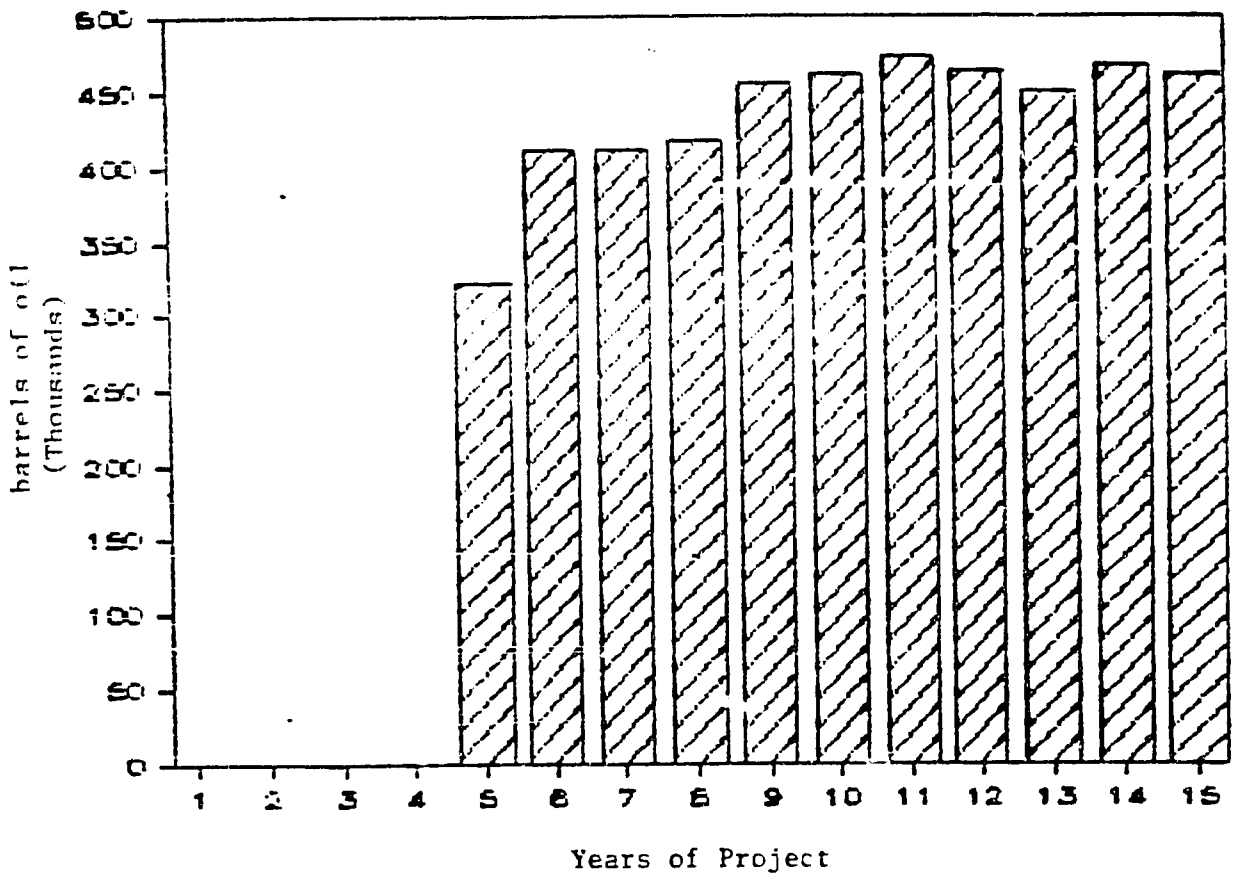


Figure II-5: Annual Oil Displacement



5.3 The Steam Boiler

The boiler has the following specifications:

Rating:	450,000 lbs/hour of steam
Steam pressure:	1250 psi
Steam temperature:	850°F
Boiler feedwater (BFW) temp.	370°F
Boiler efficiency:	75 percent

The boiler will have automatic controls for start-up, operation and shutdown to improve reliability and safety, and to maintain a steady steam supply and power output. It will have an auxiliary burner and combustion control system to regulate the use of auxiliary oil fuel under conditions when bagasse firing is not adequate.

A new cooling water and boiler feed water system will be installed. The condensing turbine will need about 20,000 gpm of cooling water. The supply of this water, which may come from several sources, needs to be examined in a detailed feasibility study.

5.4 The Steam Turbine and Generator

The turbo-generator has the following specifications:

Turbine:	multi-stage (15-20), double, controlled, extraction turbine
Generator:	45,000 Kw, 13.8 kv with brushless exciter
Inlet steam:	450,000 lbs/hour at 1200 psig and 850°F
Extraction:	1) 130,000 lbs/hour of steam at 200 psig and 525°F to be used in the existing back pressure turbines which drive the mills in the sugar factory 2) 56,000 lbs/hour of 25 psig steam to be used in the boiling house for juice evaporation (augmented by exhaust steam at the same pressure from the turbines in the milling department)
Condenser:	two-pass surface designed to fit available cooling water conditions

Due to the use of back pressure steam in the sugar factory when it is in operation, the maximum steam flow through the condenser is expected to be about 300,000 lbs/hour during the cane-crushing season. The condenser load will be increased to over 325,000 lbs/hour during the off season.

The gross power generated will be a function of the total steam production which is, in turn, a function of the total fuel availability. Approximately 7% of the gross output will be used for power plant auxiliary equipment; about 3 MW will be used for irrigation pumping on the estate lands and an additional 3 MW will be needed for factory operations during the cane harvesting season. Electricity can be generated at any voltage but preferably in the range of 13.8 kv; separate transformers will step up the power for the grid and step it down for use in the factory. Precise estimates of net power availability for the JPS grid will be made in the course of the detailed project feasibility study; preliminary estimates by the assessment team indicate that the net power output will be about 25 Mw during the cane harvesting season and 45 Mw during the off-season.

5.5 Plant Capital Costs

Estimates of the capital cost of the power plant are shown in Table II-4. They are based on the costs of similar, but not identical, power plants built in Hawaii 5 to 10 years ago and on current equipment cost data acquired from vendors. This $40 million investment takes place over the first four years of the project, as detailed in the section on Financial and Economic Analysis.

Table II-4: Power Plant Cost Estimate

Item	US$ x 1000*
Fuel System	790
Steam Generator	14,237.5
Turbo-Electric Generator	19,062.5
Site Preparation & Civil Work	1,437.5
Management and Monitoring	1,145
Contractors Home Office	1,467.5
Field Distributables	2,300
Total Estimated Cost	US $40,440.00

*Actual investments are in both US$ and J$, at the ratio 70:30. J$4=US$1

Note: Training estimated to be US $500,000 and annual maintenance US $500,000 plus J$ 4,000,000.

The process of final design and costing will require six to eight months. Both the steam generator and the turbo-generator will be custom-designed units; the final cost will be influenced by the degree of efficiency and reliability designed into the plant during the project definition phase. In addition to the capital costs listed (See Table 7) the project budget should include funds for the training of power plant personnel and annual power plant maintenance costs of US $500,000 plus J$ 4,000,000.

III. FINANCIAL AND ECONOMIC ANALYSIS

1. Introduction

This chapter presents the results of the financial and economic analyses of the cane/energy project. The principal purpose of the financial analysis is to determine whether it is an attractive investment. It is concerned with the project's financial benefits and costs, and the distribution of those benefits and costs over time and among the various entities directly involved in the project, namely, the Clarendon Sugar Company and the large and small farmers whose cane it purchases for milling. Since the project involves both the production of sugar and power, there is a separate financial analysis of the power plant portion of the project, which involves an investment in domestic and foreign resources equivalent to US$40 million.

The financial analysis is followed by an economic and social analysis in which the project's contribution to the Jamaican economy is assessed, focusing on its contribution to the solution of Jamaica's problems of unemployment and the foreign trade deficit, and the distribution of the benefits and burdens among the various participants, including the government of Jamaica, the Clarendon Sugar company, the large and small farmers, and workers.

The difference between the financial and the economic and social analyses is that the former deals exclusively with cash flows, while the latter employs shadow or accounting prices, that is, the social opportunity costs of inputs and outputs. Thus, for example, from the standpoint of an enterprise, wages are a cost in financial analysis. But increased employment and wages are benefits received by workers. The opportunity cost of labor, as distinguished from its financial cost, is what the workers would have earned in the absence of the project. The difference between the wages paid and the opportunity cost of labor is the benefit received by the worker from the project and is counted as a benefit in economic analysis.

Similarly, foreign exchange benefits and costs can be valued not at the official exchange rate as it is in financial analysis, but at a hypothetical or "shadow" exchange rate, the value that foreign exchange at the margin contributes to the economic welfare of Jamaica. Additional foreign exchange can be used to finance investment expenditures requiring purchases of capital goods and services from abroad which would otherwise have to be foregone. The shadow exchange rate is calculated to show the gain to the economy that foreign exchange earnings represent and the sacrifice involved in the expenditure of foreign exchange. In economic terms, it measures the opportunity cost of a marginal unit of foreign exchange.

Any alleviation of the shortage of foreign exchange will promote investment by Jamaican enterprises and will increase government

revenues by permitting the importation of a variety of consumer goods not produced in Jamaica but whose importation would increase government tariff revenues. Similarly, any venture which promotes stable and/or increased employment contributes to the Jamaican economy. Thus, the purpose of shadow-pricing labor and foreign exchange is to ensure that, other things being equal, projects which give employment and which save or earn foreign exchange will be given priority over projects that provide less employment and which consume foreign exchange.

2. Methodology

The methodology employed is that of discounted cash flows. Capital expenditures are counted when they are made, eliminating the need to calculate depreciation allowances and use other accounting practices which do not actually involve the receipt or expenditure of cash. All costs and benefits are calculated in 1984 prices. Over the period encompassed by the analysis, this assumes that changes in the price level will affect benefits and costs equally. Foreign exchange benefits and costs are calculated in US dollars, and when conversion into foreign or domestic currency is required, it is done at the official exchange rate, currently about J$4=US$1. Note that in the economic analysis, the conversion is done at a rate of J$5=US$1 to reflect the willingness of the government of Jamaica to spend J$5 in domestic resources to gain one additional US dollar, or its equivalent, of foreign exchange.

A discount rate of ten percent employed in the financial analysis represents the marginal cost to Jamaica of access to foreign borrowing from one of the international lending agencies. It has been selected arbitrarily since currently many loans are being negotiated at variable rates. Such borrowing has financed a high proportion of total government investment expenditures over the past decade and the ten percent discount rate may be used as a first approximation. More useful in project ranking is the internal rate of return (IRR). The difference between ten percent and the IRR may be taken as the net financial benefit of the project compared with a project barely worth undertaking.

The difference between the financial IRR and the economic IRR may be taken as a measure of the other social and economic benefits of the project. Given the shortage of capital in Jamaica, the scarcity of foreign exchange, and the high level of unemployment, projects supported by the government should be supra-marginal with respect to both financial and economic and social criteria.

The first calculation of financial benefits and costs is done on an incremental basis; that is, taking the differences between current (1984) benefits and costs and future benefits and costs. The lands, mill, irrigation system, and equipment in their present condition are considered "sunk costs," and only the costs of the additional capital improvements, equipment and machinery, and power plant are taken as costs in the incremental analysis. A second calculation of financial benefits

and costs is made in which the land is valued as though it were being rented at its annual value in alternative uses, and the existing improvements and equipment at their salvage values, or their values in some alternative use. The purpose of this second calculation on a "non-incremental basis" is to help answer the question as to whether or not the land should continue to be devoted to the production of sugar cane or should be devoted to some other agricultural use.

The financial analysis of the power plant was made by discounting the expenses and revenues directly attributable to the energy portion of the project. These included the capital investment in the power plant, the increase in field costs and irrigation costs both of which are the result of producing cane for energy, and the operating costs of the power plant. Only the power revenues and the power and fuel savings of the mill and irrigation system were included as benefits.

The results of the financial and economic analyses indicate that the project can be expected to realize a substantial rate of return both financially and economically. Not only does the project appear to enjoy a high financial rate of return on an incremental basis, but can be expected to turn a company which has been consistently losing money into one that has the prospect of earning a very satisfactory return (non-incremental basis). The prospect is one in which the company can be expected to free itself from the need of subsidies, contribute substantially to government revenues, save foreign exchange, provide secure employment for its current labor force, and employ many hundreds of additional workers.

3. Project Costs

The project will require an investment of J$31.5 millions to restore and renovate the mill and irrigation system, of which J$12.52 million will consist of the foreign exchange required to finance the capital expenditures. Additional machinery will be required which will have to be imported involving a cost of US$6.5 million over the first five years of the project. The power plant will require an investment of J$51.6 million and US$27.1 million. The amount of investments and their timing over the first four years are indicated in Table III-1.

Field costs per acre will increase because the cane energy system will use more fertilizer, water and chemicals, and because higher yields and the associated trash will be more expensive to harvest. The costs per ton of cane, however, will decrease. Table III-6 (Appendix D) is a worksheet showing how these costs were calculated. Harvest labor costs for the estate, large private farms, and small farms were based on the actual costs incurred by the estate in the 1982-83 crop year, calculated from financial data provided by the estate's management. The costs for the large and small farms per ton of cane were considered to be somewhat lower in 1982-83, J$4.00 per ton compared with J$5.61 per ton on the estate. Planting costs were based on the estate budget for planting in 1984. A fifty percent increase was allowed for energy varieties. Other field operating costs were based on the estate financial reports for the 1982-83 crop year.

The wage bill for field labor at the Monymusk estate amounted to $3,351,000 during the crop year 1982/83. Assuming an average annual wage in that year of J$4,000, this represents the employment of over 810 field workers by the estate. Based on the acreage in the estate and the private farms, the latter are estimated to have employed an additional 600 field workers. The total number employed is expected to increase as a result of the project by 800 or more by the fifth year. The remaining increase in field costs is attributable to increased fertilizer use, an increase in the number of times the cane must be irrigated (11 instead of 7), and the other costs incurred to obtain the increase in yields.

Table III-1: Investment Required by the Monymusk Project: Years 1-4

Year	Cost Item	Jamaican Expenditures (J$million)	Foreign Exchange Expenditures (US$million)
1	Mill Costs	10,724	1,500
	Irrigation system	1,900	315
	Machinery	--	1,278
	Power Plant	--	--
	Total first year	12,624	3,093
2	Mill Costs	3,500	500
	Irrigation system	1,900	315
	Machinery	--	1,674
	Power Plant	15,481	7,900
	Total second year	28,881	10,389
3	Mill Costs	3,500	500
	Irrigation system	--	--
	Machinery	--	1,627
	Power Plant	25,800	13,457
	Total third year	29,300	15,584
4	Mill Costs	3,500	500
	Irrigation System	--	--
	Machinery	--	1,948
	Power Plant	10,318	5,706
	Total fourth year	13,818	8,154
	TOTAL, first four years	J$ 76,622	US$ 37,220

NOTE: Further expenditures for machinery will be required annually after year 4 but can be financed out of earnings. No provision has been made for working capital.

4. Financial Analysis

4.1 Benefits

The financial benefits of the project are derived from the increased production of sugar and molasses, the generation and sale of electricity, and savings effected in the mill and cane yard. The sugar is priced at US$0.11 per pound. This represents a saving in foreign exchange, since sugar produced in Jamaica is exported under preferential terms to the EEC and the U.S. as a result of increased quotas, and Jamaica imports sugar to satisfy the domestic market shortfall. The price of US$0.11 is substantially less than the prices projected by the World Bank during the next decade. Because world sugar prices are currently low, a conservative estimate is justified. However, Jamaican authorities, even during the current depressed sugar market, are paying a landed price above US$0.11 per pound. Any increase in prices will make the project more worthwhile. It is significant that even at this low price placed on the increased sugar output of the project, expected financial returns are attractive.

The price of molasses represents a similarly conservative estimate. The price of J$132 (US$73) is less than half of the price in the U.S., currently US$68 to US$88 (f.o.b., New Orleans). Its opportunity cost f.o.b. Jamaica is in the range of US$48, or J$196 at the official exchange rate. Since the molasses will probably be used in the domestic liquor industry, the lower price was chosen and thus, if anything, the molasses benefits are understated.

The value of the fuel oil saved by the generation of electricity from the cane is based on a world price of US$30 per barrel and the current electric system efficiencies in Jamaica. In the near term, the price of oil is expected to continue to be soft. But after 1990 prices are expected to increase in real terms at 2-2.5 percent per year. Thus, the price of US$30 per barrel for the fuel saved also appears to be very conservative when carried, as in this analysis, over the life of the project, and considering that more expensive diesel is used to generate a portion of Jamaica's electricity. Power is currently sold at a price more than adequate to compensate for the capital employed in power plants and to provide for an adequate return on the investment, owing in large part to the recent removal of subsidies and recent devaluations.

The domestic benefits were conservatively estimated in this analysis at the value of annual depreciation of the power plant over a thirty year life and to provide for a 10% return on the investment. The power authorities in Jamaica are expected to agree to a price that will compensate for the oil that would have to be imported, the capital employed, and to provide a return of 10 percent. Table III-2 shows the (implicit) prices for electricity to be charged the power grid and they range from a high of US$0.097 per kilowatt hour in the fifth year to less than US$0.08 in the fifteenth year.

Table III-2: Calculation of the Price/Kwh Charged to the Power Grid

Year	Total Power Sold (1000 Mwh)	US$ Cost ($000)	J$ Cost ($000)	US$ Cost Equivalent $000	US$ Price per Kwh
5	155	9675	21313	15003.25	.0967952
6	198	12347	20780	17542	.0885960
7	197	12317	20248	17379	.0882183
8	201	12516	19715	17444.75	.0867898
9	219	13659	19182	18454.5	.0842671
10	221	13825	18649	18487.25	.0836527
11	227	14192	18116	18721	.0824714
12	223	13890	17584	18286	.082
13	216	13498	17051	17760.75	.0822257
14	225	14027	14027	17533.75	.0779278
15	222	13858	13858	17322.5	.0780293

In addition to the foregoing benefits, the mill and irrigation system will save their large current bill for electricity and fuel oil. The estimates of these benefits were made by calculating the fuel oil equivalent per megawatt-hour saved plus the direct saving in the oil consumed to produce the steam used in the mill. In addition, allowance was made for the fact that the mill's purchases of oil and electricity include a substantial margin for distribution costs. These were estimated by calculating a return on capital and an allowance for depreciation in the proportion used to calculate sales to the power grid.

4.2 Internal Rate of Return

Given the estimates of financial costs and benefits calculated in the manner just described, the project has a net present value of US$75.6 million employing a discount rate of ten percent, and an internal rate of return of nearly 30 percent. That is to say, the investment required will yield a substantial return. The calculation is shown in Table III-7, Appendix E.

When analyzed on a non-incremental basis, including the values assigned to the land and mill as costs, the project has a present value of US$4.19 million with benefits and costs discounted at ten percent, and an internal rate of return of nearly 11 percent. That is to say, it is worth keeping the Monymusk estate in the production of sugar cane by adding the production of power and the new investments needed to do so. In effect, this analysis recommends "saving" the entire operation as an economic enterprise. (See Table III-11, Appendix E.)

An analysis of the portion of the project devoted to the production of electricity indicates that the power plant has a present value of US$45.6 million, employing a discount rate of 10 percent and an internal rate of return of 23.5 percent. Analyzed separately, the power plant

thus appears to be financially justified and reinforces the conclusion that the cane/energy project is worth undertaking. This calculation is shown in Table III-9, Appendix D.

5.0 Economic Evaluation

5.1 Employment

The opportunity cost of unskilled labor is very low given the extremely high levels of unemployment in the cities and in the rural areas of Jamaica. Any field worker job created by the project can be assumed to be filled by an unemployed person directly or indirectly. The unemployed are assumed to find some sort of activity which provides them with the means of survival. The shadow price of labor has been estimated at 25 percent of the wage received. For each J$4000 of field labor, a social opportunity cost of J$1000 has been estimated, with the difference representing the benefits accruing to the worker.

Current labor contracts provide for support of workers during a guaranteed work year of 240 days. Some of the benefits to workers will thus result in savings to the estate since the mill is expected to operate the full 240 days. These benefits are not separately estimated.

5.2 Other Sugar Benefits

Monymusk sells its sugar to the Sugar Industry Authority (SIA) which is the marketing agency for all the sugar produced in Jamaica. The authority pays sugar producers less than the revenue it receives in both the domestic and foreign markets. However some of the revenue is used to subsidize the producers. The economic benefit assumed for the purpose of this analysis is equal to the subsidies received by the estate and the farmers, which are eliminated by the project.

5.3 Foreign Exchange

Since three-fourths of the sugar produced in Jamaica is sold in the preferential markets of the EEC (U.K.) and the U.S., the SIA imports sugar for Jamaica's domestic consumption. The increased production of sugar will make possible a reduction in imports and directly save foreign exchange. Similarly, the power generated and the mill fuel savings will conserve on the use of oil, saving foreign exchange.

The net foreign exchange benefits resulting from the project are valued at J$5=US$1 in this economic analysis. At the same time, the foreign exchange costs of the project will have to be revalued similarly. This is accomplished by increasing the net foreign exchange benefits and costs by 25 percent.

5.4 Economic Value of the Project

The economic value of the project resulting from the preceding adjustments using a discount rate of 10 percent increases to US$137.2 million. The economic internal rate of return increases to 39.7 percent. The calculation is shown in Table III-8, Appendix D.

6.0 Detailed Analysis of Costs

6.1 Agricultural Field Costs

Table III-3 shows the increased costs of field operations associated with the project, both for existing Jamaican varieties and the new cane varieties introduced over the course of the project. Their costs are described below.

Irrigation Costs. Irrigation costs are expected to increase as a result of the increased number of times that the fields will be irrigated, eleven instead of seven. The increase was based on the water supply costs incurred by the Clarendon Sugar Company in 1982/83, J$3,695,100 in irrigating approximately 10,000 acres, or a cost of J$369.50 per acre. Costs are expected to increase to J$580.64, an increase of J$211.14 per acre.

Fertilizer, Chemical, and Fuel Costs. Fertilizer costs are expected to amount to J$385 per acre for the project, an increase of J$120 over traditional operations. The estate's financial reports for 1982-83 show that field operations consumed 11,377 gallons of lubricants, 82,582 gallons of diesel oil and 22,764 gallons of gasoline. These were conservatively priced at US$12, US$1.25, and US$1.25 per gallon respectively, for a total of US$268,206, or US$26.82 per acre. Chemicals were estimated at US$13.28 to bring the cost per acre to US$40 or J$160 per acre. Because these products are imported, they are shown in the analyses as foreign to make for greater ease in economic analysis.

Table III-3: Increased Field Costs Per Acre
(J$)

Cost Item	ESTATE		SMALL FARMS		LARGE FARMS	
	Jamaican Variety	Energy Variety	Jamaican Variety	Energy Variety*	Jamaican Variety	Energ Variet
Irrigation	211.14	211.14	211.14		211.14	211.14
Fertilizer	120	120	120		120	120
Fuel and chemicals	160	160	160		160	160
Harvest labor	267.29	379.79	110		290	290
Other harvest	131.38	210.21	52.55		131.38	210.21
Total	889.91	1081.14	653.69		822.52	991.35
Add for:						
Spring Planting	434.88	434.88	434.88		434.88	434.88
Rattoons	69.04	69.04	69.04		69.04	69.04
Total Planting Crop	1324.69	1516.02	1088.57		1257.4	1426.23
Total Rattoon Crop	958.85	1150.18	722.73		891.56	1060.39

*Small farms are not expected to introduce the new varieties.

Harvest Labor. It is expected that labor costs for the harvesting of cane under the project will increase by 50% per ton compared with traditional cane. This is due to the greater density of cane stands and to the fact that the cane is not burned before harvest. The actual harvest labor cost incurred by the estate in 1982-83 was J$1,077,100 with a harvest of 192,000 tons, or J$5.61 per ton and J$107.71 per acre at a yield of 19.2 tons per acre. However, the private farms yielded an average of 25 tons per acre, and the current wage payment is reported to be J$4.00 per ton. The yields on the estate and large farms are expected to be 50 tons per acre for the Jamaican varieties of cane under the project and 65 tons per acre for the new energy varieties. Yields on the small farms are expected to increase to 35 tons per acre.

It is believed that improved management practices and increased applications of fertilizer and herbicides would increase yields on the estate and bring its costs more in line with the large private farms. A traditional labor harvest cost per ton of J$5.00 is assumed, increasing to J$7.50 per ton with the energy variety. For the large farms, a traditional labor cost of J$4.00 per ton is assumed and a cost of J$6.00 per ton for the energy variety. The resulting costs are shown in the calculations in Table III-4.

Table III-4: Calculation of Harvest Labor Costs

Item	Estate	Large Farms	Small Farms
Traditional Cane			
Cost per ton	5.61	4	4
Tons per acre	19.2	25	25
Cost per acre	107.712	100	100
Cane/Energy, Jam. Variety			
Cost per ton	7.5	6	6
Tons per acre	50	50	35
Cost per acre	375	300	210
Cane/Energy, New Variety			
Cost per ton	7.5	6	6
Tons per acre	65	65	35
Cost per acre	487.5	390	210
Incremental Cost Per Acre			
Jamaican Variety	267.288	200	110
New Variety	379.788	290	110

Other Harvest Costs. Other harvest costs are assumed to increase in proportion to the number of tons harvested. The estate in 1982-83 had "other harvest costs" of J$1009, or J$5.255 per ton.

Planting Costs. The increase in cane planting costs is based on the budget for planting 1696 acres on the estates in 1984. It showed a labor cost per acre of J$123.11 and other costs of J$964.4, excluding irrigation costs and fertilizer. Land preparation costs included in the above, J$311.71, and labor costs, J$123.11, are assumed to double for an increase of J$434.88 per acre.

Rattoon Costs. The 1982-83 financial records of the estate show labor costs of J$679.00 per acre. These are assumed to double approximately with cane cultivation under the project. All field overhead costs are assumed to remain constant. Table III-5 summarizes the field costs for rattoon crops under conventional management, new management for Jamaican varieties, and new management for energy varieties.

Table III-5: Average Estate Field Costs: Traditional Management and New Management, Rattoon Crop (US$)

	Per Acre	Per Ton	Per lb/sugar (at .084%)
Conventional Management Jamaican Variety	1170.50	50.89	.084
New Management Jamaican Variety	2129.35	42.59	.059
New Management Energy Variety	2320.68	35.70	.05

6.2 Mill Costs

Mill operating costs (other than energy) are assumed to remain the same. The investment in an improved cane yard and mill equipment are assumed to enable the mill to process the increased tonnage of cane at the same total operating cost.

There are, however, mill savings. The mill in 1982-83 consumed from the grid 4,316 Mwh of electricity, the irrigation system 9,718 Mwh, and the mill consumed 978,877 gallons of fuel oil. To produce the grid electricity required 29,200 barrels of oil, which has a value at US$30 per barrel of US$876,000. The gallons of fuel oil saved were equivalent to 28,456 barrels of oil with a value of US$853,672, for a total saving of US$1.73 million.

In addition, the mill will save overhead and distribution costs. These are assumed to be equal to the depreciation on the facilities required to produce electricity plus a 10 percent return on the investment. The Jamaican dollar savings are assumed to be in the same proportion to the value of the fuel saved as is the case with the electricity sold to the grid by Moneymusk under the project. In the case of fuel oil savings, a 25 percent allowance was made for distribution costs.

6.3 Land and Mill: Non-Incremental Analysis

The purpose of the non-incremental analysis is to assist in determining whether or not it is worthwhile, despite the large financial returns to the investment, to continue devoting the estate to sugar production. For this purpose, it is necessary to value the land and mill at their opportunity costs. The government values land capable of being irrigated at J$3,000 to J$4,000 per acre. These prices would appear to indicate that the marginal product of such land is J$300 to J$400 per year, capitalizing at 10 percent. (J$4,000 is equal to J$400/.10, assuming an income of J$400 in perpetuity and an interest rate of ten percent.) The opportunity cost of the land in the non-incremental analysis was taken at the higher cost of J$400 per year.

If the mill were devoted to other uses than the production of sugar, it would have very little value and, given the condition of the equipment, the latter has little value as well. Although the balance sheet of the Clarendon Sugar Company at the end of September 1983 showed fixed assets of J$21.9 million, the latter included the distillery which was not included in this analysis at all. The remaining assets were thus valued at J$4 million as the value that they might have in some other hypothetical use. The historical cost, or the book value, is a "sunk" cost and has little bearing on what the assets would be worth in some other use. Assuming that the distillery has a value of about J$6 million, the remaining book value would be about J$16 million, and the salvage value has been estimated at one-quarter of the latter, or J$4 million.

6.4 Demonstration Costs

At the beginning of the first year of the project, a plot of 500 acres will be planted in Jamaican varieties of energy cane. The costs of this initial planting, cultivation, and harvesting have been included in this analysis as equal to planting, cultivation, and harvesting costs under the new management system. In fact, this initial planting will be used for training and the costs will be greater. Foreign and Jamaican consultants will be employed to monitor the planting, cultivation, and harvesting and to train the staff of the estate. A separate budget has been prepared and it is expected that all of the additional costs associated with this portion of the project will be borne by a grant from an international agency.

Nevertheless, some costs of monitoring and ongoing training have been included. These are shown in the analysis as extension and

training, including J$215,000 in the first year and J$70,000 in all subsequent years. Provision has also been made for employing foreign consultants as needed and US$150,000 has been allocated for this purpose in the first two years of the project. It is expected that the costs of the foreign specialists will be included in the grant referred to above.

7. Financial Requirements and Returns, Non-Incremental Analysis

To calculate the financial requirements and returns on a non-incremental basis, cost items not included in the incremental analysis were added. These include the land values for each year and the mill values in both the initial and final periods. The calculations are shown in the Table III-11, Appendix D. It reveals that by the fifth year, the mill will have been restored to profitability. The net cash flows required to be financed during the first four years amount to US$79.7 million. It should be recalled that the estate has been losing the equivalent of about US$7 million per year in recent years and these losses are included in the US$79.7 million. At maturity in the tenth year, it will be returning about US$20.0 million per year, without any subsidies being required. As soon as the power plant comes on stream in the fifth year, the project will show a positive net cash flow of the equivalent of US$11.3 million.

Moreover, the estimates of the benefits have been conservative. There appears to be no reason to use sensitivity analysis to determine the vulnerability of the project to changes in sugar prices inasmuch as commodity forecasts of future prices substantially exceed the values assumed in this analysis and the power prices have been calculated at cost. Any profits on the latter will accrue to the Jamaican power company.

8. Financial and Economic Evaluation of Power Plant

The power plant itself represents an investment US$40.0 million of which the equivalent of US$12.9 million represents an expenditure of Jamaican resources. In Table III-9, Appendix D, the investment and operating expenditures and expected receipts from the sale of power and the savings in fuel and power currently being consumed by the mill and irrigation system were subjected to discounted cash flow analysis with the results indicated earlier, namely that the power plant has a present value of US$45.6 million, employing a 10 percent discount rate, and an internal rate of return of 23.5 percent.

Since a major portion of the power plant's benefits and expenditures are in foreign exchange, both were restated at the shadow exchange rate of J$5:US$1. Moreover, since the increased employment is due to the cane/energy techniques in the field, employment benefits were included in the calculation. The result was a present value of US$60.5 million, employing a discount rate of 10 percent, and an internal rate of return of 25.9 percent (see Table III-10, Appendix D)..

APPENDIX A

Varieties

An "energy" variety is a sugar cane variety whose genetic attributes allow for a high production of biomass (stalk, leaves, and tops; also see Figure A-1). For Jamaica where sugar production is still a viable industry, the variety should also possess the ability to produce satisfactory amounts of sugar even when cane tonnage and fiber production are stressed.

Commercial sugarcane varieties which appear to have high tonnage properties in response to proper agronomic inputs are available in Jamaica from the Sugar Industry Research Institute (SIRI). These varieties were identified and evaluated on the basis of visual observation by cane breeding specialists and information provided by Jamaican agronomists. Of eleven varieties considered, five were considered unsuitable as candidates for biomass production in the proposed pilot project because of rust susceptibility, poor growth performance, or both. Six varieties appear to be rapid growing with excellent tillering and large cane population per acre. Their characteristics are presented below.

(a) BJ 74 52

Variety BJ 74-52 (originating from the cross UCW 5465 X BJ 74227) has good germination, rapid early growth with good tillering and ratooning ability, and an erect growth habit (suitable for mechanical harvest). No rust infection was observed on this variety. It has an average-to-good sucrose content. This variety appears to have promise as a biomass producer.

(b) BJ 74-51

Variety BJ 74-51 (UCW 54-65 X CR 6101) is characterized by uniform growth, good tillering and ratooning ability, average-to-good sucrose content, and is resistant to both smut and rust.

(c) BJ 70-13

Variety BJ 70-13 (UCW 54-65 X CR 6101) has good germination, good tillering and ratooning ability, high tonnage and good juice quality. It is reportedly resistant to smut and rust.

(d) BJ 70-15

Variety BJ 70-15 (UCW 54-65 X CR 6101) is characterized by good germination, strong growth vigor, and thick stem with an average tillering ability. It is resistant to both smut and rust.

(e) MY 54129

Variety MY 54129 (Parentage unknown) was imported into Jamica from Cuba. It is characterized by a rather thick stem with strong growth vigor and average tillering ability. It is resistant to both smut and rust.

39

(f) UCF 5465

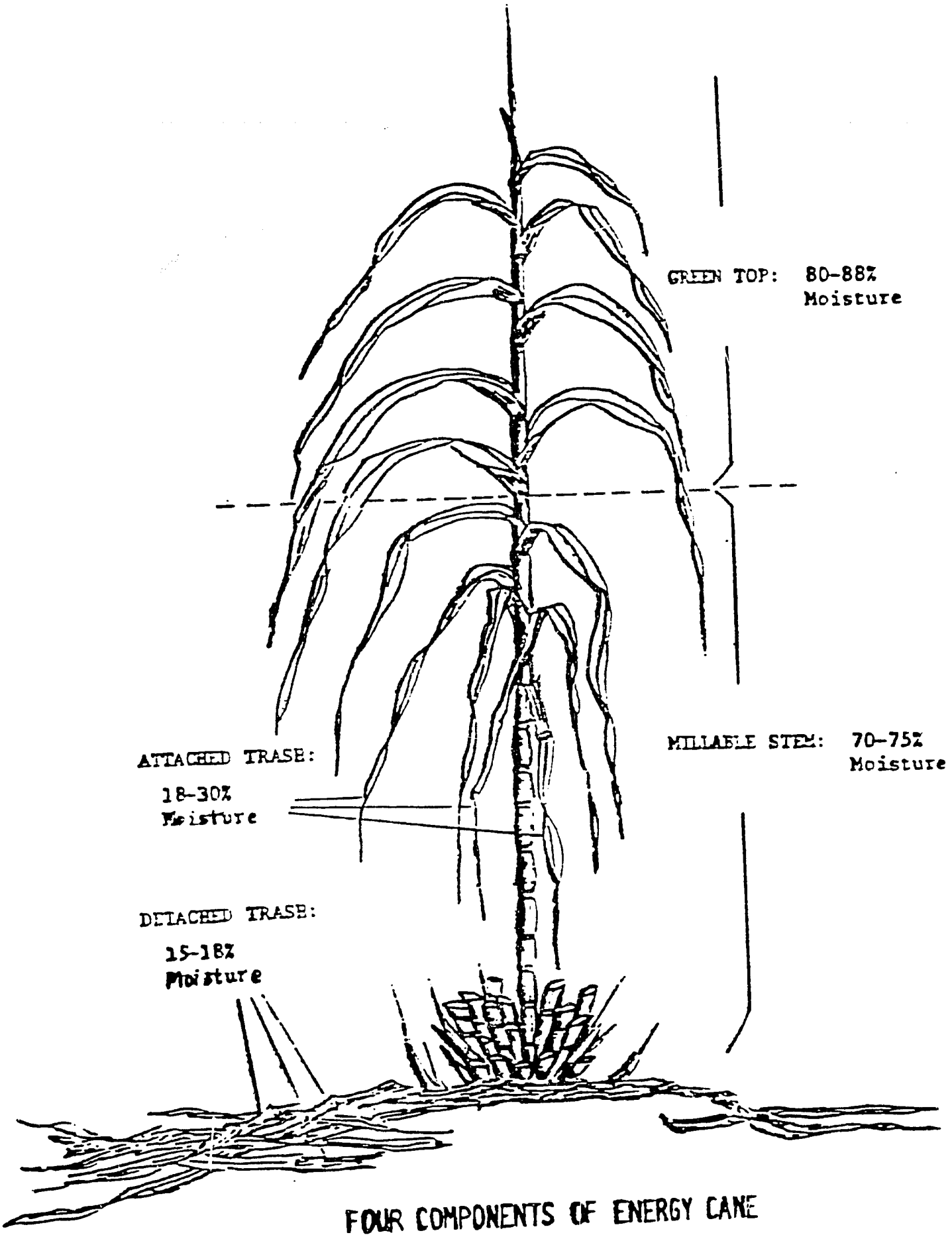
Variety UCW 5465 (B 42231 X B 41227) is reportedly adaptable to almost all soil types including salty lands at the Monymusk Estates. It accounts for 50 percent of the total acreage in cane in Jamaica in the 1980 crop. This variety is known to be a sweet cane but with average to low fiber content.

Varieties BJ 74-52, BJ 74-51, BJ 70-13, BJ 70-15, and MY 54129 are recommended for testing in the proposed pilot farm for energy cane production. In case of seed shortage of any variety mentioned above UCW 5465 can be used as a substitute variety.

There are sugarcanes available in other cane growing countries which should be introduced to Jamaica as well as untested local varieties which should be evaluated as new "energy" varieties."

35

Figure A-1: The Cane Plant



APPENDIX B

Trash Harvesting

The procedure for raking and baling trash is as follows:

Two days following the harvest and removal of cane from the field a hay rake of the disc type mounted to the drawbar of the low HP tractor will enter the field, raking and turning over the trash at the same time, leaving it in neat rows, for a second turning in two days. This hay rake is transported on adjustable ground wheels. The rake has seven free-wheeling discs, with 40 wire teeth on the margin of each disc. When the rake is adjusted so that the teeth touch the ground, they will be set into motion by the forward motion by the forward movement of the tractor. This motion turns and moves the trash, accumulting it in a row behind the moving tractor. Two rakes hitched to the right and the left of the tractor will rake a swath of 17.5 feet in a single pass.

On day five, or when the trash is dry, the baling system, drawn by a 100 HP tractor will enter the field, collecting and baling the dried trash that has been roed up. The baling system intended for use in this instance will make a single, square bale that weighs 0.74 ton, at the ideal dryness.

Under ideal conditions, 18 tons of trash can be baled in an hour of 24 bales per hour of 0.74 tons each. Because these bales have a dense outer shell, they are assured maximum protection from moisture penetration.

The baled trash is then collected from the field with a hydraulic operated bale fork and placed n trailers for transport to staging areas or directly to the electricity generating facility.

Bales should be stored in open fenced areas, that are fenced for security reasons. Due to the "thatch-like" outer shell, water will penetrate only one or two inches in the most heavy rain shower. The low moisture content of the trash bale (20 percent moisture) will minimize the risk of spontaneous combustion.

APPENDIX C

Tropical Grasses

Of the tropical grasses, other than species of Saccharum that have been evaluated for its biomass energy potential, "Napier" or "Elephant Grass," of the Genus Pennisetum appears to be the most promising. Another grass worthy of mention is "Sordan" a hybrid of Sorghum and Sudan grass which are two species of the genus Sorghum.

Data on Napier Grass production in Jamaica is limited to that produced as green feed for dairying and other livestock industry. Figures that are available indicate that 32 long tons of dry biomass per acre per year can be easily produced. With adequate inputs of water and fertilizer, it is quite possible that this potential could be doubled.

A pilot planting of 50 acres has been favorably considered for the pilot farm study. The conservative figure of 35 long tons of dry matter per acre per year is the yield being considered. This would be harvested every six months at an average of 17.5 T/Ac. A plant crop and five ratoon crops are programmed, and are expected to yield a minimum of 5,000 tons from 50 acres during this three-year period.

The fields for the planting of Napier Grass would have to be level enough to permit flood irrigation. The field would be subject to two plowings, two knifings in a criss-cross pattern and would receive a final harrowing prior to the appplication of fertilizer, broadcast, by hand. The next operation would be the incorporation of the fertilizer with a "rototiller," ensuring that it is well mixed, breaking up all clods of soil, leaving the field in fine tilth, ready for the final operation of furrowing.

Planting material will be long canes of Napier Grass with all of the trash removed. The grass used would be kept for several days prior to the scheduled planting. These long canes are kept in the shade and not permitted to dry out. Frequent application of water may be necessary to help break dormancy of the fertile eyes from which grow the young plantlets.

These seed pieces are placed in the recently prepared furrows with 25 to 30 percent overlap, indicating that 4 to 4.5 tons of Napier seed cane will be required per acre, in furrows with five-foot centers.

The seed pieces will promptly be covered by machine, with a follow-up inspection and covering up by hand where necessary. Immediately, or as soon as possible the field must be irrigated with at least three inches of water, preferably applied with an overhead portable irrigation system. The second wetting should follow in 12 to 16 days, depending on the soil type, with the subsequent four cycles of water programmed, to be applied as required.

At approximately 13 weeks from planting, the second and final application of fertilizer is made, the rate and formulation is determined by soil analysis.

At six months of age, the first cutting will be made with a rotary scythe mower-conditioner, which not only cuts the Napier canes down, but also shatters the canes, ensuring even faster solar drying.

The cut Napier grass will be raked and turned over twice with two to three days spacing between rakings. The same equipment and technique as already decribed in the section on cane trash will be employed for this operation.

The shattered, dry Napier Grass will then be baled and removed from the field in approximately seven to ten days. The equipment and technique employed is described also in the section on cane trash.

Following the removal of the baled Napier grass, the field will be reconditioned for the first ratoon crop. This will consist of a shallow knifing of light cultivation, parallel with the furrow direction, without disturbing the Napier Grass stools. Following this operation, three inches of irrigation should be applied, with the subsequent four cycles being applied as required.

At thirteen weeks following the renovation, fertilizer is applied at the rate and formula determined by soil analysis.

A six months of age from the renovation, this first ratoon crop is harvested using the same procedures and machinery already described.

Four more ratoon crops may be made before a reduction in yield is noted, at which time the field should be prepared and replanted either to Napier Grass or Sugar Cane. These four subsequent ratoon crops are reconditioned in the same manner employed in the conditioning of the first ratoon.

Sorand, mentioned in the first paragraph, should be evaluated experimentally, as a short-term (two-months) tropical grass for boiler fuel.

APPENDIX D

List of Tables

Table

III-6 Worksheet: Analysis of Field Costs, 1984-1999
III-7 Financial Analysis of the Monymusk Project, Incremental Basis
III-8 Economic Analysis of the Monymusk Project, Incremental Basis
III-9 Financial Analysis of the Power Plant
III-10 Economic Valuation of the Power Plant
III-11 Financial Requirements and Returns, Non-Incremental Basis ($000)

Table III-6

Worksheet: Analysis of Field Costs. 1984-1999

Year	0	1	2	3	4	5	6	7	8
Acres under cultivation	18000	18000	18000	18000	19000	20000	20000	20000	20000
Traditional management	18000	17500	16500	12500	7500	5500	800	0	0
Estate	10000	9500	8500	6500	3500	3500	0		
Large farms	4000	4000	4000	3000	2000	1000	0		
Small farms	4000	4000	4000	3000	2000	1000	0		
Energy Management	0	500	1500	5500	11500	14500	19200	20000	20000
Planting, estate		500	1000	2000	4000	1000	4000	1000	2000
Rattoons, estate			500	1500	3500	7500	8000	11000	10000
Planting, large farms				1000	1000	1000	1000	0	1000
Rattoons, large farms					1000	2000	3000	4000	3000
Planting, small farms				1000	1000	1000	1000	0	1000
Rattoons, small farms					1000	2000	3000	4000	3000
Cultivation Costs									
Cane/Energy, cost increase									
Planting, estate		661	1325	2648	5299	1325	6063	1515	3032
Rattoon, estate			478	1437	3356	7190	7671	12652	11502
Planting, large farms				1256	1256	1256	2675	0	1425
Rattoon, large farms					892	1782	2675	3565	3180
Planting, small farms				1089	1089	1089	0	1089	1089
Rattoon, small farms					723	1446	2167	2891	2167
TOTAL COST INCREASE		661	1802	6434	12615	14091	20924	20625	22398
less fertilizer,fuel,chemicals		140	420	1540	3220	4060	5376	5600	5600
TOTAL JAMAICAN $ COSTS		521	1383	4894	9395	10031	15548	15025	16798
TOTAL U.S. $ COST		35	105	385	805	1015	1344	1400	1400

Table III-6
Continued

Year	9	10	11	12	13	14	15
Acres under cultivation	20000	20000	20000	20000	20000	20000	20000
Traditional management	0	0	0	0	0	0	0
Estate	0						
Large farms	0						
Small farms	0						
Energy Management	20000	20000	20000	20000	20000	20000	20000
Planting, estate	4000	1000	4000	1000	2000	4000	1000
Rattoons, estate	8000	11000	8000	11000	10000	8000	11000
Planting, large farms	1000	1000	1000	0	1000	1000	1000
Rattoons, large farms	3000	3000	3000	4000	3000	3000	3000
Planting, small farms	1000	1000	1000	0	1000	1000	1000
Rattoons, small farms	3000	3000	3000	4000	3000	3000	3000
Cultivation Costs							
Cane/Energy, cost increase							
Planting, estate	6063	1516	6063	1516	3032	6063	1516
Rattoon, estate	9200	12652	9200	12652	11502	9200	12652
Planting, large farms	1425	1425	1425	0	1425	1425	1425
Rattoon, large farms	3180	3180	3180	4242	3180	3180	3180
Planting, small farms	1089	1089	1089	0	1089	1089	1089
Rattoon, small farms	2167	2167	2167	2891	2167	2167	2167
TOTAL COST INCREASE	23130	22032	23130	21300	22398	23130	22032
1s. Fert., Fuel, Chm.	5600	5600	5600	5600	5600	5600	5600
TOTAL JAMAICAN $ COSTS	17530	16432	17530	15700	16798	17530	16432
TOTAL U.S. $ COST	1400	1400	1400	1400	1400	1400	1400

Table III - 7

Financial Analysis of the Monymusk Project, Incremental Basis

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
CAPITAL EXPENDITURES							
Irrigation	J	1900	1900				
	F	315	315				
Machinery	J						
	F	1278	1674	1627	1949	2122	1800
Mill Costs	J	10724	3500	3500			
	F	1500	500	500			
Plant Costs	J		15481	25800	10318		
	F		7900	13457	5706		
Sub-total	J	12624	20881	29300	10318	0	0
	F	3093	10389	15584	7654	2122	1800
OPERATION COSTS							
Agricultural, field	J	522.3	1384.1	4893.6	9395	10031	15420
	F	35	105	385	805	1015	1344
Irrigation	J			376	376	376	376
	F						
Mill Costs	J	no change					
	F						
Plant Costs	J					6385	6385
	F					600	600
Extension & Trng.	J	215	70	70	70	70	70
	F	180	180				
Sub-total	J	737.3	1454.1	5339.6	9841	16862	22251
	F	215	285	385	805	1615	1944
REVENUES OR BENEFITS							
Sugar Sales	J						
	F	0	0	2759	7121	8452	12707
Molasses Sales	J	0	0	648	1672	1984	2983
	F						
Power Sales	J					21313.1	20780.3
	F					9675	12347
Electricity Savings	J					1931	1931
	F					876.5	876.5
Fuel Oil Savings	J					699.2	699.2
	F					699.2	699.2
Sub-total	J			648	1672	25927.3	26292.5
	F			2759	7121	19702.7	26629.7
NET OPRT. BENEFITS	J	-737.3	-1454.1	-4691	-1869	9065.3	4142.5
	F	-215	-285	2374	6316	18087.7	24685.7
TOTAL NET BENEFITS	J	-13361	-22335	-33991	-18497	9065.3	4142.5
	F	-3308	-10674	-13210	-1338	15965.7	22885.7

NET PRESENT VALUE CALCULATION

Discount Rate		10%	30%	29.5%	29.8%	29.7%
NPV of J$ benefits	J	-30744.7	-38571.4	-38760.5	-38647.6	-38685.4
@J4=US1	FJ	-7686.17	-9642.86	-9690.13	-9661.89	-9671.35
NPV of US$ benefit	F	83286.11	9282.945	9926.543	9537.017	9665.726
TOTAL NPV, US$		75599.95	-359.911	236.4150	-124.877	-5.62311

Table III-7, Continued

Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
2034	2101	1772	1743	1731	1731	1731	1731	1731
								-101238
---	---	---	---	---	---	---	---	---
0	0	0	0	0	0	0	0	-101238
2034	2101	1772	1743	1731	1731	1731	1731	1731
12921	16263	16995	15897	16995	15700	16263	16995	15897
1400	1400	1400	1400	1400	1400	1400	1400	1400
376	376	376	376	376	376	376	376	376
6385	6385	6385	6385	6385	6385	6385	6385	6385
600	600	600	600	600	600	600	600	600
70	70	70	70	70	70	70	70	70
---	---	---	---	---	---	---	---	---
19752	23094	23826	22728	23826	22531	23094	23826	22728
2000	2000	2000	2000	2000	2000	2000	2000	2000
12566	12927	14791	15109	15770	15203	14582	15435	15198
2950	3035	3472	3547	3702	3569	3423	3623	3568
20247.5	19714.7	19181.9	18649.1	18116.3	17583.5	17050.7	16517.9	15985.1
12317	12516	13659	13825	14192	13890	13498	14027	13858
1931	1931	1931	1931	1931	1931	1931	1931	1931
876.5	876.5	876.5	876.5	876.5	876.5	876.5	876.5	876.5
699.2	699.2	699.2	699.2	699.2	699.2	699.2	699.2	699.2
699.2	699.2	699.2	699.2	699.2	699.2	699.2	699.2	699.2
---	---	---	---	---	---	---	---	---
25827.7	25379.9	25284.1	24826.3	24448.5	23782.7	23103.9	22771.1	22183.3
26458.7	27018.7	30025.7	30509.7	31537.7	30668.7	29655.7	31037.7	30631.7
6075.7	2285.9	1458.1	2098.3	622.5	1251.7	9.9	-1054.9	-544.7
24458.7	25018.7	28025.7	28509.7	29537.7	28668.7	27655.7	29037.7	28631.7
6075.7	2285.9	1458.1	2098.3	622.5	1251.7	9.9	-1054.9	100693.3
22424.7	22917.7	26253.7	26766.7	27806.7	26937.7	25924.7	27306.7	26900.7

IRR = 29.7 percent

Table III-9:
Economic Analysis of the Monymusk Project--Incremental Basis

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
ECONOMIC BENEFITS								
SIA Benefits @J0.26/lb	J			6622	17090	20255	30497	30158
Increased Labor Incomes								
Harvest	J	100.2	300.7	1102.6	2305.5	2906.9	4271.7	4516.7
Planting	J	33.4	66.9	200.7	401.4	200.7	401.4	66.9
Construction	J	3.1	5.2	4.7	2.6	--	--	--
Foreign Exchange Benefits and Costs @ J$5=US$1	J	-3308	-10674	-13210	-1338	16120	23040	22579
FINANCIAL BENEFITS	J	-13361	-22335	-33992	-18487	9065.3	4142.5	6075.7
	F	-3308	-10674	-13210	-1338	15966	22886	22425
TOTAL ECONOMIC AND FINANCIAL BENEFITS	J	-16532	-32636	-39272	-25.5	48578	62353	63396
	F	-3308	-10674	-13210	-1338	16120	23040	22579

(Cont'd)		Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
ECONOMIC BENEFITS									
SIA	J	31025	35498	36262	37848	36487	34997	37044	36475
Increased Labor									
Harvest	J	4770.2	5023.8	5277.4	5277.4	5277.4	5277.4	5277.4	5277.4
Planting	J	267.6	401.4	200.7	401.4	66.9	267.6	401.4	200.7
Constr.	J	--	--	--	--	--	--	--	--
Foreign Exchange	J	23072	26408	26921	27961	27092	26079	27461	-27055
FINANCIAL BENEFITS	J	2295.9	1458.1	2098.3	622.5	1251.7	9.9	-1055	-544.7
	F	22918	26254	26767	27807	26938	25925	27307	26901
TOTAL ECON. & FIN. BENEFITS	J	61421	68789	70759	72110	70175	66631	69129	68463
	F	23072	26408	26921	27961	27092	26079	27461	27055

CALCULATION OF NET PRESENT VALUE AND IRR:

Discount Rate		10%	39%	40%	39.7%
NPV of J$ benefits @J4=US1	J	213003	-3123	-4593	-4165
	FJ	53251	-780.7	-1148	-1041
NPV of US$ benefit	F	83971	1485.9	918.12	1083.5
TOTAL NPV (US$)		137221	705.2	-230.2	42.2

IRR 39.7%

Table III-9

Financial Analysis of the Power Plant

Year	Capital Costs (US$000)	Operating Costs (US$000)	Operating Revenues & Savings (US$000)	Increased Field Costs (US$000)	Irrigation Costs (US$000)	Net Cash Flow
1				165.58	.00	-165.58
2	11770.25			451.03	.00	-12221.28
3	19907.00			1608.40	94.00	-21609.40
4	8285.50			3153.75	94.00	-11533.25
5		2196.25	17236.53	3522.75	94.00	11423.53
6		2196.25	19775.33	5199.00	94.00	12286.08
7		2196.25	19612.13	4630.25	94.00	12691.63
8		2196.25	19677.93	5465.75	94.00	11921.93
9		2196.25	20687.73	5648.75	94.00	12748.73
10		2196.25	20720.53	5374.25	94.00	13056.03
11		2196.25	20954.33	5648.75	94.00	13015.33
12		2196.25	20519.13	5325.00	94.00	12903.88
13		2196.25	19998.93	2965.75	94.00	14737.93
14		2196.25	20389.73	5648.75	94.00	12450.73
15	-101238.00	2196.25	20087.53	5374.25	94.00	113661.03

Calculation of Net Present Value
(US$000)

10.0 percent	45610.19
23.5 percent	141.88
23.6 percent	12.49

IRR = 23.5 percent

Table III-10

Economic Valuation of the Power Plant

Year	Net Cash Flow US$000	Labor Benefits (US$000)	Foreign Exchange Benefits (US$000)	Net Economic Benefits (US$000)
1	-259.58	34.21	-132.50	-357.87
2	-12315.28	93.21	-2125.00	-14347.07
3	-21609.40	327.02	-3460.50	-24742.89
4	-11533.25	677.38	-1627.75	-12483.63
5	11423.53	776.90	2558.93	14759.36
6	12286.08	1168.28	3144.68	16599.04
7	12691.63	1145.90	3123.18	16960.71
8	11921.97	1259.46	3172.93	16354.31
9	12748.73	1356.31	3458.68	17563.71
10	13056.03	1369.53	3500.18	17925.73
11	13015.33	1419.71	3591.93	18026.96
12	12907.88	1336.08	3516.43	17756.39
13	14737.97	1386.26	3418.43	19542.61
14	12450.73	1419.71	3550.68	17421.12
15	113661.03	1336.08	3508.43	118505.54

Calculation of Net Present Value
(US$000)

10.0 percent	60522.00
25 percent	1299.26
26 percent	-56.19
25.9 percent	72.42

IRR = 25.9 percent

Table III-11

Financial Requirements and Returns, Non-Incremental Basis ($000)

		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Total Net Benefits	J	-54439.3	-59413.1	-71069.6	-55565.0	-28012.7	-32935.5
	F	-3308.0	-10674.0	-13210.0	-1338.0	15965.7	22885.7
Add Back:							
Mill, salvage value	J	4000.0					
Land value	J	8000.0	8000.0	8000.0	8000.0	8000.0	8000.0
Net Cash Flow	J	-42439.3	-51413.1	-63069.6	-47565.0	-20012.7	-24935.5
	F	-3308.0	-20674.0	-13210.0	-1338.0	159655.7	22885.7
US$ Equivalent		-13917.8	-23527.3	-28977.4	-13229.3	10962.53	16651.83

		Year 7	Year 8	Year 9	Year 10	Year 11	Year 12
Total Net Benefits	J	-31002.3	-34792.1	-35619.9	-34979.7	-36455.5	-35286.3
	F	22424.7	22917.7	26253.7	26766.7	27806.7	26937.7
Add Back:							
Mill, salvage value	J						
Land value	J	8000.0	8000.0	8000.0	8000.0	8000.0	8000.0
Net Cash Flow	J	-23002.3	-26792.1	-27619.9	-26979.7	-28455.5	-27286.3
	F	22424.7	22917.7	26253.7	26766.7	27806.7	26937.7
US$ Equivalent		16674.13	16219.68	19348.73	20021.78	20692.83	20116.13

		Year 13	Year 14	Year 15
Total Net Benefits	J	-37068.1	-38132.9	63615.3
	F	25924.7	27306.7	26900.7
Add Back:				
Mill, salvage value	J			-101238.0
Land value	J	8000.0	8000.0	8000.0
Net Cash Flow	J	-29068.1	-30132.9	-29622.7
	F	25924.7	27306.7	26900.7
US$ Equivalent		18657.68	19773.48	19495.03

US

APPENDIX E

Additional Research Needs

The study team recommends that more detailed analysis in several areas. In the case of several of these areas, most notably the study of water resources and extension needs, the team feels that additional research should precede the commitment of major resources to the project. In the case of others additional analysis is less vital but would considerably improve the chances of successful implementation.

1. Water Resources

The Monymusk estate has been suffering from unseasonal rainfall shortages for several years and the aquifer upon which the cane growers depend for their irrigation water--more than 60 pumps serve the public estate alone--has been declining in quality. Salinity problems have become so severe that more than a thousand acres has been lost to productive agriculture.

Although it may be reasonable to expect that "normal" rainfall patterns will return, the water supply is so crucial to the cane/energy system that a careful, separate examination of this matter is urgent. There are several technical studies of the water situation in the Clarendon area, and there have been proposals for major irrigation projects. These should be examined and, if necessary, a separate ground water expert should be asked to consider the matter.

2. Agricultural extension

Many hundreds of small farmers depend today on the sale of sugar cane to one of the two mills in the Clarendon area, Monymusk and New Yarmouth. The introduction of new agricultural techniques relying on expensive fertilizer and new varieties may be partly beyond their reach, but it seems likely that many of them will seek to adapt to the new conditions if the cane/energy system succeeds. Therefore, we have estimated that four thousand acres of land will show a 40% increase in productivity over the fifteen years of project life we examined. Other farmers may choose to grow tonnages of low-sugar cane or tropical grasses and sell the lignocellulosic material to the power plant as supplemental fuel. It appears that the plant may be able to utilize quantities of this material, and a local trade in biomass is likely to arise.

Of particular interest here is the question of the pricing formula to be used to compensate small holders for cane delivered to the factor. Currently many small farmers sell their cane to transport brokers, who obtain a price and pay the farmers on the basis of the average sugar content of the load. This scheme, while practical, provides little incentive for the individual farmer to raise productivity on his or her land. In addition, no formula has been devised that accounts for the fuel and sugar value of material delivered.

Finally, the entire problem of extension needs and the overall impact of the project on the small farmers and local residents requires careful investigation. If, as we expect, this project will transform the character of cane agriculture to much higher levels of productivity, the market for traditional, low-yield sugar cane of the kind grown by marginal farmers may experience a gradual decline. Government programs to help people adjust to these changes should be examined with care in advance.

3. Key Markets: molasses, sugar, alcohol

One of the attractive features of the cane/energy approach is that managers have considerable flexibility in adapting to changing market conditions. Currently, both sugar and energy are valuable products, and, as we have depicted it, the operation depends heavily on both of them. It is possible, however, that the sugar market may continue to worsen and the energy market may continue to improve. If this is the case, managers may choose a different mix of products from the operation. For example, a different approach, which has been advocated in Puerto Rico, is to take the juice from the cane and use it to produce rum. This saves the energy used in sugar production and directs the sucrose to another use. The Jamaican rum industry currently relies on "final" molasses (or blackstrap) and therefore there is no market for higher grade molasses or unprocessed "high-test" molasses. There may be an export market for this product, however, and the tradeoff with sugar production needs to be examined. Another option for Jamaica in the future might be to utilize the sucrose to produce fuel alcohol. This would displace imported oil in the transport system and would reduce the cost of refinery operations by allowing the refinery to produce lower octane gasoline (alcohol acts as an octane booster, reducing the energy required to refine each gallon of gasoline). Again, this use of high-test molasses needs to be examined against alternative uses, including the extraction of sugar to displace imports.

4. Agricultural Experimentation

As the chapter on energy cane agriculture indicates, the introduction of new varieties of cane is expected to play an important part, in the long run, in boosting the production of biomass. Furthermore, its seems very likely that there are significant opportunities for further genetic improvement of biomass yields in both sugar cane and tropical grasses. Because of this, planning for an expansion of Jamaica's capacity to import, and test, new varieties, is critically important. Included in a study of agricultural research needs should be a close examination of some of the more promising strains--such as U.S. 67-22-02--to ascertain their resistance to cane diseases. Such an examination is time consuming, and must be completed before they can be imported. As the estimates of production in this study indicate, a delay of several years in the introduction of new varieties would have a

measurable effect on the production of sugar as well as energy. Only careful planning can prevent this, since introducing even a single new variety can take a year or more due to quarantine requirements.

5. Training

Success of this project depends heavily on the ability of those in charge to train personnel in Jamaica to manage the new cane production system. Accordingly, a careful review of training needs in the field, mill and power plant should be completed early in the planning process. Indeed, the process of expanding new production of cane, beginning with the 500 cane plot, should itself be reviewed is a training exercise as well as a means of proving agricultural technique. Jamaica has many skilled persons with experience in sugar production and in the management of power systems. However, it appears that the sugar industry has suffered a serious loss of top- and middle-level management and technical expertise in the recent years of decline. In addition, the operation of an integrated cane energy system will demand unusual abilities and, most important, a change in conceptual orientation: the mill in such a system is no longer just a sugar refinery, but a fuel supplier; the power system is not just a mill and boiler, but a large-scale, grid-connected Plant.

It would seem particularly appropriate, in this respect, for the Agency for International Development to consider enrolling qualified Jamaican management and technical personnel in the Conventional Energy Training Program (CETP). Under this program it is often possible to arrange internships with successful private corporations. If internships could be arranged, for example, with Hawaiian sugar companies that are producing large amounts of energy, Jamaicans may be able to benefit directly from an examination of operations with similar goals.

Cane Production for Sugar and Electric Power in Jamaica

ACTION PLAN -- PHASE 1:

Cane Production at Monymusk

October, 1984

Sponsored by the

U.S. Agency for International Development
Bureau for Science and Technology
Office of Energy
Bioenergy Systems and Technology Project
Washington, D.C. 20523

and

USAID/Jamaica
Kingston, Jamaica

52

Preface

This Action Plan was prepared by request of the Office of the Prime Minister for Phase 1 of the project, "Cane Production for Sugar and Electric Power in Jamaica." A technical and economic feasibility assessment by the same title has been prepared under separate cover, representing the efforts of a team of technical specialists, GOJ officials and USAID staff over the period May - September 1984. This action plan presents activities, budget and a schedule for the first fourteen months of the proposed cane/energy project.

52

Table of Contents

	Page
Preface	i
1. Introduction	1
2. Activity Description	2
3. Further Studies	4
4. Estimated Budget, Equipment	5

FIGURES, TABLES

Figure 1:	Phase 1 Activities and Implementation Schedule	6
Table 1:	Estimated Budget: Phase 1	7
Table 2:	Equipment Utilization	9
Table 3:	Estimated Hours Utilization	10

54

ACTION PLAN -- PHASE I

Cane Production at Monymusk

1. Introduction

The USAID/GOJ study team which prepared the assessment, "Cane Production for Sugar and Electric Power in Jamaica," selected the Monymusk Sugar Estate and surrounding cane growing areas as the pilot project site for undertaking a "cane/energy" program. The cane/energy approach changes the aim of cane production from producing just sugar products to producing a combination of sugar and electric power. Present GOJ thinking contemplates raising the Monymusk area's cane production to meet international sugar production levels by using and improving traditional practices. By contrast, the proposed cane/energy approach will introduce new cane management practices in accordance with the aim of getting high levels of both sugar and power production.

The project at Monymusk will encompass approximately 20,000 acres of estate lands and private farms. The overall objective of an expanded program will be to bring between 70,000 and 90,000 acres of land under a cane/energy management system which would have the potential to generate foreign exchange savings and earnings of US$100 - 130 million annually from the production of 270,000 tons of sugar, 90,000 tons of molasses and one million megawatt-hours (MWh) of electricity.

The cane/energy approach will give the Jamaican sugar industry a stable co-product in energy, while also consolidating the lucrative export sugar market and the significant domestic market. It will bring to the industry a diversity it does not have as well as an ability to adjust to changing economic conditions. Lastly, it is anticipated that the sugar industry will be able to attract substantial private investment based on the results of the pilot project.

This action plan details the activities for the first 14 months, or Phase 1, of the cane/energy project at Monymusk, beginning in November 1985. Further planning for the pilot project as well as an expanded program will be detailed during the latter stages of this phase.

55

2. Activity Description

Activities in this work plan are based on the following assumptions regarding important components of the project:

(1) that USAID will be providing technical support through the first 5 years of the program;

(2) that the foreign exchange capital funds can be obtained from private sector and/or international financial institutions and donor agencies;

(3) that the local capital and operational funds will be available from:

(a) the Government of Jamaica, and

(b) the Venezuelan/Mexican oil agreement financing facility.

Furthermore, in order to assure success of the pilot effort and final area development, it is recommended that a team of experts be formed by the USAID Mission in Jamaica to manage the development of the project. This team will be located both in Kingston and at Monymusk for a period of five years and will have initial direction for the first 500 acres of the project.

In order to begin the 20,000 acre project at Monymusk, an initial plot of 500 acres will be cultivated. The primary purposes of this acreage are to introduce new cultivation management procedures, to confirm estimates of the agricultural inputs necessary to achieve target cane yields, and to train field and administrative personnel in the new cane management system. Assuming that the overall Monymusk estate is dedicated to the objectives of the cane/energy project, the management of the first 500 acres will provide a base for expansion of cultivation to the entire area. Thus, personnel should be trained in large enough numbers to provide skilled directors for cultivation of subsequent acreages.

The stages of activity included in this action plan are elaborated below. These are also illustrated in Figure 1: Phase 1 Activities and Implementation Schedule.

1) Designate lead Jamaican agency to be Implementing Agency: This is a GOJ responsibility. The Implementing Agency will be required to provide all logistical support related to the program.

2) Establish Coordinating Committee: This is a joint responsibility of GOJ and the USAID/Jamaica mission. The Coordinating Committee is an inter-agency oversight body which monitors and controls program progress. The committee also ensures that Jamaican development interests are kept paramount in the structure of the program. Suggested composition of such a committee is as follows:

i. Minister or Permanent Secretary from:
   - Ministry of Agriculture
   - Ministry of Mining and Energy
   - Ministry of Public Utilities and Transportation

ii. Representatives from:
   - Sugar Industry Authority
   - Private Sector Organization of Jamaica
   - United States Agency for International Development
   - Jamaica Public Service Company

3) Nominate U. S. Project Manager: This is a joint responsibility of USAID/Washington and USAID/Jamaica. The Project Manager is expected to possess substantial management experience in sugar cane growing operations. He would be responsible for all field related activities.

4) Nominate Jamaican Project Manager (Program Director): This is a GOJ responsibility. The Project Manager would be responsible for overall program development and direction. He would provide liaison with the various governmental agencies to ensure smooth operation of the pilot project, and would also be responsible for:

- Preparation of loan documents;
- Coordinating additional studies;
- Extension service development;
- Water supply arrangements;
- Developing policy recommendations for GOJ in bioenergy development;
- Formulation of training program;
- Design of research & development activities.

5) Assemble Specialists to begin detailed work plan: This is a joint USAID?Washington and USAID/Jamaica responsibility. The specialist team will consist of four man-years of effort, two of which are expected to be energy cane agricultural specialists from the Puerto Rican program.

6) Prepare water improvements assessment necessary for Phase 1 and outline details of water supply system: This is the responsibility of USAID/Washington. AID will organize a team of technical specialists to work with the Water Resources Division on water supply in project areas.

7) Complete detailed Phase I work plan: This is the responsibility of the Program Director. Efforts on the work plan are to be started as soon as the specialist team is in place.

8) Prepare training plan: This is a Program Director responsibility. Prior to formulating a course, subjects such as potential participants and funding sources will have to be addressed. A full time training specialist will be provided by USAID to work with a local counterpart in developing and

executing important aspects of the program. Training will be an on-going activity and will involve institutions such as CAST, VTI, JIDC and JSA.

9) Prepare Phase-1 planting programs: This is a Program Director responsibility. Plans should be presented to the Coordinating Committee for approval by March 1985.

10) Begin and implement training program: This is a Program Director responsibility. Plans will be presented to the Committee for approval.

11) Begin and implement planting and cultivation program: This is a joint Program Director and Project Manager responsibility. Plans will be presented to the Committee for approval.

12) Prepare implementation Program and begin planting Phase-2 (1500 acres). Program Director/Project Manager responsibility. Planning is to begin for the next planting phase of 1500 acres; however, implementation will await results of the cane production evaluation (step 13).

13) Evaluate cane production. The quality and quantity of early growth will provide valuable information for the future development of the cane/energy program. Both planting and production results will be presented to the committee for review and project decision making.

14) Preliminary Engineering Review: On the assumption that cane production achieves expected levels, early engineering design studies will be conducted to relate the proposed power plant to the sugar mill and the electric utility distribution system.

15) Prepare detailed project plan: This is a Program Director responsibility, in collaboration with the project management team. Development plans for subsequent acreages will be submitted for approval by the Coordinating Committee in the following areas.

- Financing
- Research and development program
- Biofuels policy
- Implementation plan
- Water supply system

Other aspects of the cane/energy program, such as extension and training, may warrant detailed development plans as well.

3. Further Studies

A number of additional studies will be needed in order to determine the most beneficial expansion of the cane/energy program and to plan cost-effective implementation of new project investments. The anticipated assessments are as follows:

58

(a) Net foreign exchange study
(b) Water supply system assessment
(c) Pricing mechanisms for cane and other biofuels
(d) Alcohol option study
(e) Prefeasibility studies on Bernard Lodge, Frome, Duckenfield and Long Pond

No dates have been established for these studies. A timetable will be developed once the planning and arrangements are in place

4. Estimated Budget, Equipment

A budget for Phase 1 activities has been prepared and is shown in the following pages. This is followed by two tables detailing agricultural equipment needs, estimated hours of utilization and projected equipment costs for the 500 acre initial plot.

59

FIGURE 1: PHASE I ACTIVITIES AND IMPLEMENTATION SCHEDULE

Schedule of Prospective Activities
for period November 1984 - March 1985

Activities

1. Designation of Lead Jamaican Agency to be Impementing Agency
2. Establish Coordinating Committee
3. Nominate U.S. Project Manager
4. Nominate Jamaican Project Manager
5. Assemble Specialists to begin detailed workplan for Phase 1 (500 acres) to include:
   (a) 2 - Agro Specialists
   (b) 1 - Irrigation Specialist
   (c) Machinery Specialists
6. Prepare Overall Assessment of Water Improvements Necessary
7. Complete Detailed Workplan Phase 1
8. Prepare Training Plan
9. Prepare Phase 1 Planting Programs
10. Begin and Implement Training Program
11. Begin and Implement Planting and Cultivation Program
12. Prepare Implementation Program and Begin Planting Phase 2 (1,500 Acres)
13. Evaluate Cane Production
14. Preliminary Engineering Review
15. Prepare Detailed Project Plan

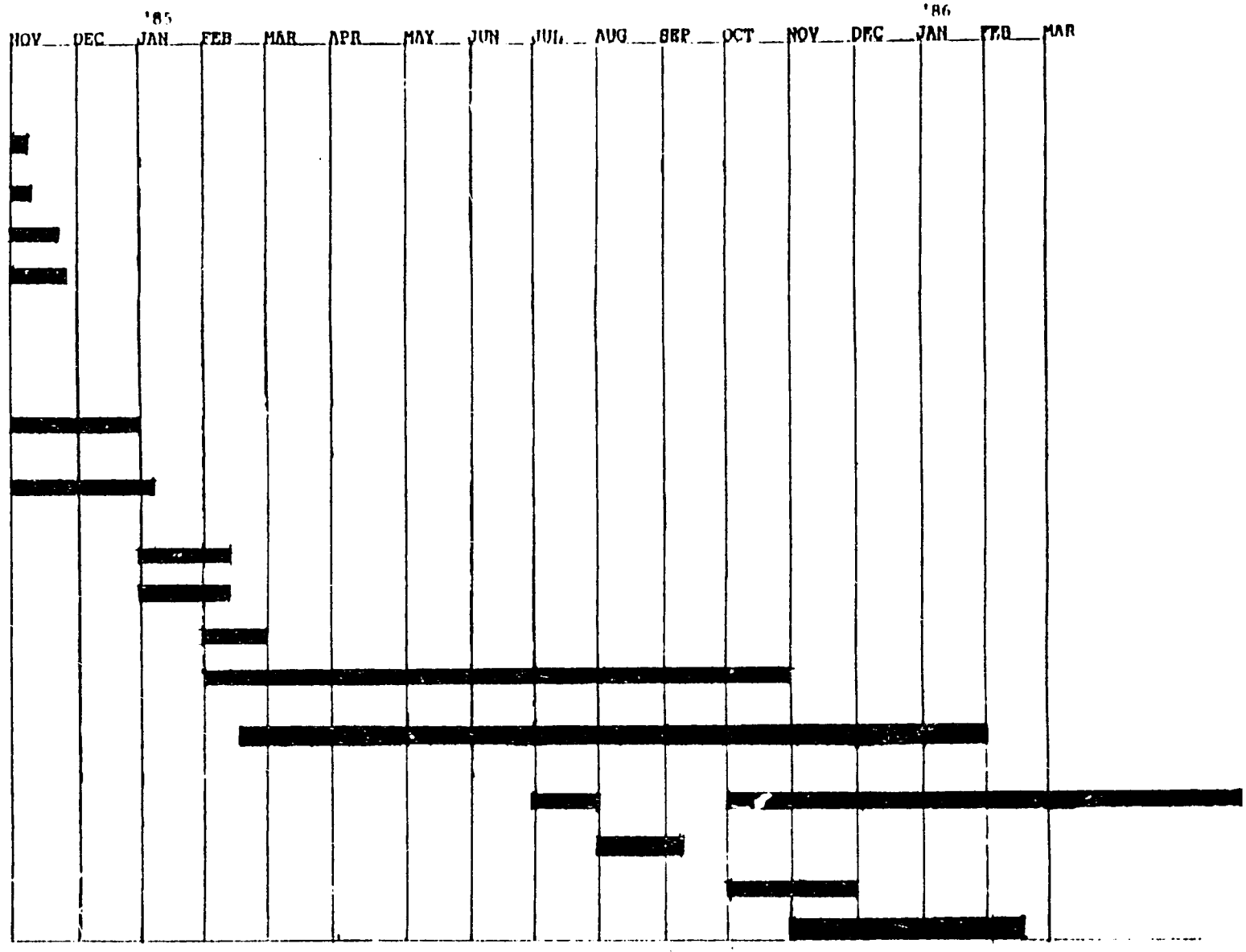


Table 1: Estimated Budget: Phase 1 -- 500 Acre Pilot Project

	US$	J$
U.S. Specialists*		
Gen'l Manager @ $12,000/mo. (incl. overhead,profit) x 12	144,000	
Agro Spec. @ $3,200/mo. from U.P.R.-overhead x 16	51,200	
Machinery Spec. @ 5,000/mo. x 4	20,000	
Training Specialist @ 3,200/mo. x 3	9,600	
Engineering Specialists @ 8,000/mo. x 3	24,000	
Subtotal	248,800	
Travel, Per Diem	67,200	
Subtotal	316,000	
Jamaican Specialists		
Assistant General Manager @ $4,500 per month		63,000
Agro Specialists @ $3,500 per month		147,000
Irrigation Specialists @ $3,500 per month		35,000
Training Specialist @ $3,000 per month		42,000
Engineering Specialists @ $5,000 per month		15,000
Machinery Specialists @ $3,000 per month		18,000
Subtotal		320,000
Travel, Per Diem (Internal Jamaica)		20,000
Subtotal		340,000
Office Space, Furniture, Equipment		
2,000 sq. ft. space @ J$120/sq.ft.		240,000
Furniture		160,000
Equipment, Office and Radio Intercom		30,000
Subtotal		430,000
Personnel Transportation: Equipment		
1 Multi-person van	18,000	
2 3/4 ton pick-up	20,000	
Subtotal	38,000	
Personnel Transportation: Operation/Maintenance		
Fuel, maintenance, insurance		66,000
Field Operation Costs		
Planting Materials 7,500 tons @ J$40 per ton		100,000
Planting 500 acres @ J$50/acres		2,500
Water Improvements J$200/acre**		100,000
Irrigation J$850/acre**		425,000
Harvesting J$6.00/ton/(30,000 tons)		180,000
Fertilizer and Chemicals @ $J400/acre		200,000
Cultivation (covered under equipment rental)		
(Cont'd)		

*Various means of recruitment: university, private sector and direct-hire.
**Figure reflects an estimate as actual cost will depend on site

61

Table 1: Estimated Budget (cont'd)

		US$	J$
Field Operation Costs (cont'd)			
Equipment Purchase (est.)			
- Sub-soiler		8,000	.
- Laser grading control		57,000	.
- Rotovator		10,000	.
	Subtotal	75,000	1,007,500
Equipment Rental			570,000
Training Equipment			
Visual aids, sound and photo lab		25,000	
Budget Summary			
Specialists (US and Jamaican*)		316,000	340,000
Office, Furniture, etc.			430,000
Personnel Transportation		38,000	66,000
Field Operations Costs		75,000	1,007,500
Equipment Rental			570,000
Training Equipment		25,000	
	TOTALS	454,000	2,413,500

*Does not include program director

62

Table 2: Equipment Utilization

Prime mover	Purpose	Implements	Purchase Price US$
1. D6-Crawler:	Clear land Tillage Earth moving In-field haulage (wet conditions) Harrowing	-Blade -Sub-soiler -10 x 36" harrow	125,000
2. 4 WD-RT-Tractor (200 hp approx) (Quick-coupling)	: Multiple-operations interrow tillage : Earth moving land-plane : Soil Shredding Rototator : Final harrowing	-Disc-ridger -Chisel -Rotovator -Fertilizer Applicator -Land Plane -Laser equipment	80,000
3. 2 WD-RT-Tractor (75 hp approx)	: Inter-row (plants) : Furrowing (plants) : Fertilizer placement : Spraying : Trash-raker-bale : General haulage (on farm)	-Spraying equipment -Furrow boddy -Fertilizer spreader -Boom-spray -Trash rake/baler -Tipper trailer	30,000
4. 2 WD-RT-Tractor (100 hp approx)	: Road-haulage (crop) : Standby for 3	-Cane trailers	45,000
5. D3 or D4 Light crawler	: In-field haulage (crop) : Alternate to 2 or 3 (out of crop)	-Cane trailers	75,000
6. Cane Loader	: Load Cane (crop) : Spot Cane Seeds (planting)		112,000
7. Back-hoe	: Excavate (construction) and maintain irrigation and drainage ditches	-Cleaning -Excavating -Loading Buckets	60,000
8. O/H-Irrigation Set Complete	: First 2 irrigations-plants and ratoons --Irrigation 50 Acs on 12 to 14 day cycle		30,000 (estimate)
9. Hand Tools	: Harvesting : Cultivation : Maintenance	-Cutting knives/files/ grinding stone -Shovels/spades -Hand tools -Back-pack sprayers.	5,000

Table 3: Estimated Hours Utilization - 500 Acs*

			Hours			
			Year 1	Year 2	Year 3	Year 4
1. D6 Crawler	- Clearing		150	--	--	--
	- Harrowing		750	--	--	--
Approx. hirage	- Sub-soil		1,000	--	--	--
rate-J$100/hrs	- Earth moving		200	--	--	--
			2,100	--	--	--
			100	--	--	--
			2,200 hrs	—	—	—
		Sub Total	J$220,000.00			
2. 4 WD-RT Tractor	Multiple-opers. inter-row (Plants/Ratoons)		100	650	650	650
180-200 hp	Land Prep:	Rotovate/soil shredding	500	--	--	--
Approx. J$60/hr		Final harrow	300	--	--	--
		Land planing/earth moving	300	--	--	--
			1,200	650	650	650
		Sub Total	J$72,000			
3. 2 WD-RT Tractor	Planting:	Furrow/cover. place fert.	1,250	--	--	--
(75 hp)						
Approx. J$40/hr	Crop Maint:	Spraying	1,275	1,275	1,275	1,275
		General haul.	250	400	400	400
	Harvest:	Rake & bale	--	1,000	1,000	1,000
			2,775	2,675	2,675	2,675
		Sub Total	J$111,000			
4. 2 WD-RT Tractor	Harvest:	Road-haulage	1,250	2,000	2,000	2,000
(170 hp)		Stand by**		250	250	250
Approx. J$48/hr			1,250	2,250	2250	2250
5. D3 or D4 Crawler	:	In field haulage	700	2,000	2,000	2,000
Approx. J$60/hr		Stand by**		250	250	250
		Sub Total	43,000			
6. Cane-loader	:	Load Cane (Crop)	250	2,000	2,000	2,000
Approx. J$80/hr	:	Load/Spot Seed Cane**	--	--	--	--
			250	2,000	2,000	2,000
		Sub Total	20,000			

6c

Estimated Hours Utilization - 500 Acs*

			Hours			
			Year 1	Year 2	Year 3	Year 4
7.	Back-hoe Approx. J$90/hr.	: Excavation/Maintenance	500	250	250	250
			500	250	250	250
		Sub Total	45,000			
8.	O/H Irrigation Set N/A		1,120	1,120	1,120	1,120
9.	Hand-tools	: Back-pack sprayers (3)				
		Total	J$570,000			

* Equipment time indicated is for normal operation; in a training mode time requirement will increase.
** Denotes out of season activity assisting in cultivation operations.