ESM-0077

Joint UNDP/World Bank
Energy Sector Management Assistance Program

Activity Completion Report

No. 077/87

Country: MAURITIUS

Activity: BAGASSE POWER POTENTIAL, 1987-2000

OCTOBER 1987

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

Purpose

The Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP) was started in 1983 as a companion to the Energy Assessment Program, established in 1980. The Assessment Program was designed to identify and analyze the most serious energy problems in developing countries. ESMAP was designed as a pre-investment facility, partly to assist in implementing the actions recommended in the Assessments. Today ESMAP carries out pre-investment activities in 45 countries and provides institutional and policy advice to developing country decision-makers. The Program aims to supplement, advance, and strengthen the impact of bilateral and multilateral resources already available for technical assistance in the energy sector. The reports produced under the ESMAP Program provide governments, donors, and potential investors with information needed to speed up project preparation and implementation. ESMAP activities fall into two major groupings:

- Energy Efficiency and Strategy, addressing the institutional, financial, and policy issues of the energy sector, including design of sector strategies, improving energy end-use, defining investment programs, and strengthening sector enterprises; and

- Household, Rural, and Renewable Energy, addressing the technical, economic, financial, institutional and policy issues affecting energy supply and demand, including energy from traditional and modern sources for use by rural and urban households and rural industries.

Funding

The Program is a major international effort supported by the UNDP, the World Bank, and bilateral agencies in a number of countries including the Netherlands, Canada, Switzerland, Norway, Sweden, Italy, Australia, Denmark, France, Finland, the United Kingdom, Ireland, Japan, New Zealand, Iceland, and the USA.

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MAURITIUS

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FOREWORD

The Energy Assessment report on Mauritius, published in December 1981, 1/ identified the country's dependence on imported fuel as the key energy sector issue. The major option to reduce this dependence is to substitute indigenous bagasse (crushed sugar cane waste) for imported fuel in power generation. This requires economizing on bagasse use in the sugar industry, handling and storing the resulting surplus, and transporting it to power generating stations for use as fuel.

In 1985, the Government of Mauritius requested technical assistance from the joint UNDP/World Bank Energy Sector Management Assistance Program to identify the economic potential for substituting bagasse for alternative fuels in power generation. Two ESMAP missions were fielded for this purpose, 2/ cofinanced by the UNDP Energy Account for Mauritius. The first, in September 1985, evaluated and costed alternative options for bulk handling bagasse for power generation. The second, in July 1986, estimated the cost and potential economic supply of surplus bagasse for power generation and the net addition to power supply that would result from its use. This report summarizes their findings.

The mission members wish to express their appreciation for the extensive assistance received from the Mauritian Government, particularly the Ministry of Energy and Internal Communications; the Central Electricity Board; the Mauritius Sugar Authority; and the many representatives and staff of the sugar mills visited, who gave most generously of their time and expertise. Valuable field support was provided by the office of the UNDP Resident Representative.

1/ Mauritius: Issues and Options in the Energy Sector Joint UNDP/World Bank Energy Assessment Program, Report 3510-MAS, December 1981.

2/ The first mission comprised Messrs. Willem Floor (Mission Leader, World Bank), Josef Leitmann (renewable energy specialist, World Bank) and Hans Peter Buess (bagasse consultant). The second mission comprised Messrs. Robin Broadfield (Mission Leader, World Bank), Josef Leitmann, Felix Adam (sugar factory consultant) and William Kenda (sugar process consultant). The report was written by Messrs. Broadfield and Leitmann. Secretarial assistance was provided by Ms. Holly Mensing.

ACRONYMS AND ABBREVIATIONS

B20	Bagatex 20 Bagasse Baling System
CEB	Central Electricity Board
ERR	Economic Rate of Return
ESMAP	UNDP/World Bank Energy Sector Management Assistance Program
FUEL	Flacq United Estates Limited
GNP	Gross National Product
GOM	Government of Mauritius
MCA	Mauritius Chamber of Agriculture
MEIC	Ministry of Energy and Internal Communications
MSA	Mauritius Sugar Authority
MSIRI	Mauritius Sugar Industry Research Institute
NPV	Net Present Value
SSRR	Societe Sucriere de Riviere du Rempart
kg	kilogram
ton	metric tonne
TPH	tons per hour
TPD	tons per day
TPA	tons per year
kW	kilowatt
MW	Megawatt
GW	Gigawatt
kJ	kilojoule
MJ	Megajoule
GJ	Gigajoule
kWh	kilowatt hour
MWh	Megawatt hour
GWh	Gigawatt hour
gallon	imperial gallon
mm	millimeters
km	kilometers
m^2	square meters
m^3/h	cubic meters per hour
b.d.	bone dry
m.c.	moisture content (all bagasse weights without indication are based on 50% m.c.
HHV	high heating value
NCV	net calorific value

EXCHANGE RATES, ENERGY COSTS, AND CONVERSION FACTORS

Exchange Rates

1985	15 Rupees (Rs) = US$1.00 1 Rupee = US$0.067
1986	13.5 Rupees (Rs) = US$1.00 1 Rupee = US$0.07

Energy Costs (Mauritian Rupees)

Fuel	Financial	Economic
Coal (delivered to FUEL)	950/ton	950/ton
Coal c.i.f. Port Louis	750/ton	750/ton
Diesel oil	13.37/gallon	8.15/gallon
Firewood	0.21-0.25/kg	0.17-0.25/kg
	22.1-26.0/GJ	17.9-26.0/GJ
Charcoal	2.40-2.75/kg	1.87-2.75/kg
	88.9-101.9/GJ	69.3-101.9/GJ

Net Calorific Value of Alternative Fuels

Fuel	Moisture Content	NCV/kg
Bagasse	50%	7,380
	20%	13,320
Coal	n.a.	27,000

Power Generation from Alternative Fuels

Fuel	kWh
Coal	1488/ton
Diesel oil	20.3/gallon

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I. SUMMARY AND PRINCIPAL CONCLUSIONS

Quantity and Cost of Potential Bagasse Savings

1.1 On average, about 1.5 million tons of bagasse are produced each year in Mauritius as a by-product of sugar manufacture. Over 95% is used by the 19 Mauritian sugar mills to produce power and process steam for their own use. Most of the balance is used by the mills to generate power for supply to the national grid. Small quantities are sold as industrial boiler fuel and animal fodder.

1.2 The sugar mills currently use bagasse inefficiently because it has limited commercial value. By raising boiler combustion efficiency and installing less energy-intensive process equipment and mill drives, the mills could economize on bagasse use and substantially increase the surplus available to substitute for alternative imported fuels.

1.3 Assuming sugar production averages 600,000-650,000 tons per year, as is envisaged by the Sugar Action Plan, the following potential bagasse savings can be achieved at 15 of the 19 existing sugar mills 1/:

(a) 103,400 tons by housekeeping measures to economize on bagasse own-use (i.e., without investment);

(b) an additional 19,100 tons at an investment cost (excluding bagasse handling and storage) of less than Rs 65/ton (US$5/ton) in associated mill modifications;

(c) a further 47,500 tons in investment cost of Rs 65-130/ton (US$5-10/ton) in mill modifications.

Technically, at least 360,000 tons of bagasse can be saved by the 15 mills, 170,000 tons of which will cost less than Rs 130 ton (US$10/ton) to save (Table 1.1). 2/ The combined cost of the investments necessary to realize this 170,000 ton saving is Rs 19 million (US$1.39 million). Whether these and related investments in bagasse handling and storage will be economic depends on the potential uses for additional surplus bagasse and the cost at which it can be supplied, relative to alternative fuels.

1/ With the exception of Beau Champ, the sample of 15 mills included all significant potential sources of bagasse supply.

2/ Assuming the full cost of the necessary investments is attributed to bagasse.

Table 1.1: QUANTITY AND COST OF POTENTIAL BAGASSE SAVINGS BY 15 SUGAR MILLS

Item	Investment Cost a/				
	0	Under US$5/ton	US$5-9.9/ton	US$10-14.9/ton	US$15/ton and over
Potential Bagasse Saving ('000 tons)	103.4	19.1	47.5	35.2	155.1
Cumulative Bagasse Saving ('000 tons)	103.4	122.5	170.0	205.2	360.3
Mill Investment Required (US$'000)	0	147	1,247	1,879	n.a.
Cumulative Mill Investment (US$'000)	0	147	1,394	3,273	n.a.

a/ Excluding bagasse handling and storage.

Source: Mission estimates.

Alternative Uses for Additional Surplus Bagasse

1.4 The highest-value potential use for additional surplus bagasse, and the only significant alternative to its use in power generation is as a fuel oil substitute for industrial process heating. Current industrial use of bagasse is less than 5,000 tons, due to the small scale of Mauritian industry and the cost of boiler conversion. There is potential for increased industrial use, particularly in the tea industry, a large user of process heat. Draft Terms of Reference for technical assistance to define this potential are attached (Annex 6). However, potential industrial bagasse demand is not significant relative to potential supply.

1.5 Power generation is by far the largest current use of surplus bagasse. In 1985, 58 GWh of grid electricity were generated from bagasse, 15% of total generation. Forty-five GWh were generated by the Flacq United Estates Limited (FUEL) (21.7 MW), Medine (10 MW) and Mon Tresor/Mon Desert (5 MW) sugar mill generating plants, which are equipped with relatively efficient condensing turboalternators. The remaining 13 GWh were generated by 11 sugar mills equipped with back-pressure generating sets. These sets operate only during the crop season and their output fluctuates with sugar factory operations. The power is neither firm nor subject to modulation by the CEB.

1.6 The highest value use of additional bagasse for power generation, based on existing facilities, would be generate firm power at the FUEL, Medine and Mon Tresor sugar mills. These generating stations are capable of generating 85 GWh, 35 GWh, and 16 GWh per year respectively from bagasse, a total of 136 GWh (35% of generation in 1985). At present, bagasse supply is insufficient for generation outside the crop season. Only FUEL currently operates year-round, burning coal during the intercrop period. Medine is planning to convert to dual bagasse/coal firing, and then would be capable of year-round operation. Mon Tresor will require a sufficient supply of bagasse for year-round operation.

1.7 Maximizing the use of bagasse at these three generating stations would require the other mills to cease generating power and instead supply surplus bagasse in bulk for use as a generating fuel to FUEL, Medine and Mon Tresor. Their maximum potential bagasse demand for year-round operation is: FUEL, 114,000 tons; Medine, 56,000 tons; and Mon Tresor, 36,000 tons, a total of 206,000 tons.

Evaluation of Bulk Bagasse Handling Systems

1.8 Facilities to handle, store, and transport bagasse in bulk will be necessary to supply the generating stations at least cost. There are four potential bulk handling options--loose piling, pelletizing, briquetting and baling. Loose piling is not recommended because of unpredictable fuel characteristics and health risks. Pelletizing, briquetting and baling are all technically feasible. In terms of cost per unit of useful energy, the proven technique of large baling (650 kg bales) is by far the least-cost handling option (Table 1.2).

Table 1.2: COST OF ALTERNATIVE BAGASSE HANDLING SYSTEMS

System Parameters	Pelletizing	Briquetting	Large Baling
Bagasse moisture content (%)	10.00	10.00	20.00
Net heating value (GJ/ton)	15.30	15.30	13.30
Cost in useful energy (US$/GJ)	2.69	2.06	1.05

Source: Mission estimates.

Potential Economic Supply of Bagasse as a Generating Fuel

1.9 It will be economic to utilize additional bagasse as a generating fuel to the point where its economic cost of supply equals the economic benefits of this use. If the bagasse substitutes for an alternative generating fuel, the benefits are the economic cost of the substitute fuel saved. If it converts previously non-firm bagasse power capacity into firm capacity, the benefits are the cost of alternative generation saved.

1.10 FUEL is already a firm power plant. If, as is planned, Medine converts to coal-firing, its capacity will also be firm. The economic benefit of increased bagasse utilization at these two plants is therefore the economic cost of the alternative fuel saved, which is coal. In mid-1986, the economic cost of coal supply was Rs 950/ton (US$70.4/ton). In terms of unit cost of power generation, this is equivalent to Rs 0.68/kWh (US$0.05/kWh).

1.11 The only potential new firm bagasse power capacity is Mon Tresor. In view of this plant's age and questionable reliability, it is unlikely to be so rated, even if sufficient economic quantities of bagasse were available for year-round operation.

1.12 The economics of coal substitution will therefore determine the potential role of bagasse in power generation over the next 5-10 years. In the longer term, there may be potential for a new bagasse-fired generating station, depending on the cost of bagasse vis-a-vis alternative generating capacity.

Bagasse Substitution at Mid-1986 Coal Costs

1.13 At the mid-1986 economic cost of coal (US$70.4/ton), and adjusting for relative fuel and boiler efficiency, it is economic to substitute bagasse for coal as a generating fuel up to a maximum delivered bagasse cost of US$23.3/ton at FUEL, and US$18.7/ton at Medine. Based on estimates of the cost of bagasse saving (where applicable), baling, storage, transport and boiler feeding, the potential supply of bagasse at less than this cost to each plant is:

(a) FUEL: 126,700 tons, of which 112,500 tons could be supplied from six other mills, 14,200 tons by installing a bagasse dryer at FUEL. This is 12,700 tons greater than FUEL's requirement for year-round bagasse generation;

(b) Medine: none; 63,500 tons of bagasse could be supplied at a cost competitive with coal, but only by diverting bagasse from the more efficient FUEL plant, where it has a higher economic value and hence should be utilized.

Bagasse Substitution at Higher and Lower Coal Costs

1.14 An increase of 10% in the c.i.f. cost of coal would make an additional 19,200 tons of potential bagasse supply to Medine from Mon Desert/Alma economic, on a coal substitution basis. A 20% fall in the c.i.f. cost of coal would make 27,100 tons of potential bagasse supply to FUEL uneconomic.

Potential Bagasse-fired Power Generation

1.15 At mid-1986 coal costs, it is therefore economic to substitute all coal burnt at FUEL with bagasse. This would result in 55 GWh of additional bagasse power generation at FUEL. Assuming Constance, the nearest bagasse supplier, were to invest in a bagasse baling and storage facility by 1989, 8 GWh of additional bagasse power could be produced in 1990. The balance of 47 GWh could result by 1992, if other competitive bagasse suppliers made the necessary investments in 1991.

1.16 An increase of 10% in the c.i.f. cost of coal would justify an additional 7.5 GWh of bagasse-fired generation from Medine, based on bagasse supply from Mon Desert/Alma. A 20% decrease in the c.i.f. cost of coal, which is close to World Bank projections for the period 1986-95, would reduce additional bagasse-fired generation at FUEL from 55 GWh to 48 GWh (Table 1.3).

Table 1.3: ECONOMIC POTENTIAL FOR ADDITIONAL BAGASSE POWER GENERATION (GWh)

Plant	Delivered Cost of Coal		
	US$59.3/ton	US$70.4/ton	US$81.5/ton
FUEL	48	55	55
Medine	0	0	7.5
Total	48	55	62.5

Source: Mission estimates.

Impact of the Bagasse Payment to Planters

1.17 There are no major economic uses for additional bagasse in Mauritius other than power generation. Its economic opportunity cost is therefore zero. Maximum economic benefit from bagasse use will be realized only if all the economically-competitive supply for power generation is so utilized.

1.18 Currently, Mauritian law requires a payment to cane planters of Rs 100/ton (US$7.4) for bagasse used for any purpose other than sugar production. The impact this bagasse payment will have on the financial cost bagasse supply for power varies from mill-to-mill, depending on the mill's contribution to the total sugar crop. At a c.i.f. cost of coal of Rs 750/ton (US$55.6/ton), equivalent to a delivered cost of Rs 950/ton (US$70.4/ton), it is estimated that the payment would make 31,800 tons of economic bagasse supply to FUEL financially uncompetitive and a further

27,000 tons marginally competitive. If the uncompetitive bagasse was displaced, the resulting economic cost to Mauritius from higher substitute coal imports would be Rs 7.7 million (US$573,000) per year. If the marginally-competitive supply was also lost, the total economic cost would be Rs 14.3 million (US$1,060,000) per year. At a c.i.f. cost of coal of Rs 616/ton (US$45.6/ton) the payment would made 95,100 tons of economic bagasse supply to FUEL financially uncompetitive, at an economic cost to Mauritius of Rs 19.0 million (US$1.4 million) per year.

1.19 Avoidance of this economic cost requires either (a) elimination of the bagasse payment or (b) modification of the payment system so that it does not affect the competitiveness of potential economic bagasse supply. The benefits of the maximum economic use of bagasse would then be shared between the sugar millers, the planters, the Central Electricity Board (CEB), and power consumers.

Investment Returns and Risks of a Bagasse Power Generation Project

1.20 A potential bagasse power generation project, defined as the supply of 114,800 tons of baled bagasse for power generation at FUEL by the six least-cost potential suppliers--Constance, Belle Vue, Societe Sucriere de Riviere du Rempart, Beau Plan, St. Antoine and FUEL itself--would require capital investment of Rs 57.3 million (US$4.2 million), primarily in baling and storage facilities. Annual operating and transport costs would total Rs 11.0 million (US$0.8 million) and annual benefits Rs 35.8 million (US$2.7 million) in a full year of operation (Table 1.4). Based on these estimated costs and benefits, the project has a net present value (NPV) of US$4.8 million at a 14% rate of interest. Assuming no significant distortions in the Mauritian economy, its economic rate of return (ERR) is 36%. There is a risk that costs could be higher and benefits lower than estimated. Under a worst-case scenario of costs 20% higher and benefits 20% lower, the NPV falls to US$1.1 million and the ERR to 19%.

Table 1.4: ESTIMATED COSTS AND BENEFITS OF A BAGASSE POWER PROJECT (US$'000)

Item	Year 1	Year 2	Year 3	Years 4-20
Costs				
Investment	919	0	3,327	0
Operating	135	160	517	517
Transport	0	31	31	298
Total Costs	1,054	191	3,875	815
Benefits	0	436	436	2,652
Net Benefits	-1,054	+245	-3,439	+1,837

Source: Mission estimates

Recommended Bagasse Baling Demonstration Project

1.21 Although the recommended large bale bagasse handling technique is internationally proven in Hawaii, Latin America and Africa, the technology is unfamiliar to Mauritian sugar mills. Hence, a demonstration bagasse handling, storage and bale breaking project is recommended to familiarize potential bagasse suppliers with the technology. The project involves the supply of 18,700 tons of baled bagasse from Constance, the nearest mill with a substantial current bagasse surplus, to FUEL, the least-cost bagasse-fired power generating station. The project's capital cost is Rs 12.4 million (US$919,000) and its annual operating cost is Rs 2.6 million (US$191,000). At an interest rate of 14%, it has an NPV of US$390,000. Its ERR is 22%. A 10% increase in costs and decrease in benefits lowers the NPV to US$267,000 and the ERR to 18%.

II. ENERGY SECTOR STRATEGY AND THE POTENTIAL ROLE OF BAGASSE

Energy Sector Strategy

2.1 Roughly half of Mauritius' current energy requirements are met by bagasse, most of which is used by the island's 19 sugar mills for their own energy needs. Of the other half, about 30% is met by petroleum products, 15% by wood, and the balance by small quantities of hydropower and coal.

2.2 The country's key energy problem is the burden of energy imports on the balance of payments. From US$10 million in 1973, energy imports rose to over US$50 million in 1984, equivalent to 15% of total export earnings. Although the recent decline in world oil prices has provided temporary relief, oil prices are expected eventually to return to their pre-1985 level. Unless effective action is taken to reduce fuel imports, the energy-induced balance of payments constraint will again become severe.

2.3 The energy strategy recommended for Mauritius is to substitute cheaper indigenous fuels for imported oil and coal, where cost-effective, and to use energy more efficiently. Outside the transport sector, where there is little prospect of indigenous fuel substitution, the greatest user of oil and coal is power generation. The growing industrial sector is also a significant oil consumer. This report focuses on the potential for substituting indigenous bagasse for imported fuel in power generation. Analysis is also needed of the least-cost means of satisfying industrial energy demand.

Power Subsector Strategy

2.4 A power demand forecast for Mauritius to the year 2000 has been prepared as input to a least-cost power expansion plan. From a level of 327 GWh consumed in 1985, the plan hypothesizes three alternative scenarios for the growth of power demand (Table 2.1). All imply substantial additions to existing generating capacity and energy production.

Table 2.1: POWER DEMAND FORECAST, 1985-2000
(GWh)

Year	Base Case	Low Scenario	High Scenario
1985	327	327	327
1990	501	471	556
2001	803	647	1033

Source: Mauritius: Power Sector Demand Forecast, SWECO (Sweden), January, 1987.

2.5 The existing power generation system is composed of hydroelectric and thermal plants. The hydroelectric plants comprise the Champagne power station (30 MW) and eight smaller hydroelectric stations. The thermal plants consist of the diesel-fueled St. Louis (86.1 MW) and Ft. Victoria (62.4 MW) plants, operated by the CEB, and 14 sugar factory plants. The largest of these, the 21.7 MW FUEL plant, burns bagasse and coal. The second largest, the 10 MW Medine plant, burns bagasse, but will shortly add coal-burning capability. The 12 other plants are exclusively bagasse-fueled. The capacities of the various plants are summarized in Table 2.2.

Table 2.2: INSTALLED, AVAILABLE, AND FIRM POWER CAPACITY, 1985
(MW)

Type of Plant	Installed capacity	Available capacity	Firm capacity
Oil thermal	148.5	120.5	75.0
Hydro	54.1	51.3	10.0
Sugar factory			
FUEL	21.7	18.0	18.0
others	63.4	17.1	0.0
Subtotal	85.1	35.1	18.0
Total	287.7	206.9	103.0
Peak demand			85.0

Source: CEB.

2.6 The relative contribution to total energy produced by each type of plant in 1985 is shown in Table 2.3. The oil thermal stations produced almost half of the electrical energy, the hydro stations just under 30%, and the sugar factories 27%. Of the latter, 15% was generated from bagasse and 12% from coal.

Table 2.3: ENERGY PRODUCTION BY TYPE OF PLANT, 1985

Type of Plant	Energy Production	
	(GWh)	(%)
Oil thermal	173.6	44
Hydro	114.0	29
Sugar factories		
FUEL bagasse	28.3	7
Coal	45.2	12
Others (bagasse)	29.5	8
Subtotal	103.0	27
Total	390.6	100

Source: CEB.

2.7 The potential for further development of hydro capacity is limited. All coal and oil must be imported. The only indigenous fuel with significant potential for increased use in power generation is bagasse. It is therefore in the interest of Mauritius to make maximum use of this fuel in power generation, to the extent it is the least-cost alternative and has no higher-value use.

Future of the Sugar Industry and Bagasse Supply

2.8 The potential availability of bagasse for power generation and other purposes in inexorably linked to the future of the sugar industry in Mauritius. Despite recent expansion and diversification of the industrial sector, sugar production continues to be the single most important economic activity in the country, accounting for just under 50% of total merchandise exports and a quarter of total employment in the organized sector. Maintaining the output and productive efficiency of the industry therefore remains vital to the economic health of Mauritius.

2.9 Annual output of processed sugar declined from an average of 660,000 tons between 1972 and 1979 to 585,000 tons between 1980 and 1983. However, favorable climatic conditions resulted in production of 645,000 tons of sugar during the 1985 season, and production in 1986 is expected to top 700,000 tons. Over the last ten years, sugar cane production has ranged from a minimum of 4.3 million tons during a cyclone year to a high of 6.6 million tons. The Sugar Action Plan is based on maintaining output at a level of 600,000-650,000 tons of processed sugar per year. This provides a firm basis for analysis of the potential contribution that bagasse can make to the island's fuel supply.

III. POTENTIAL DEMAND FOR SURPLUS BAGASSE

Introduction

3.1 Currently, about 95% of the bagasse available in Mauritius is used by the sugar industry to produce low pressure steam for sugar process heating and high pressure steam for driving mill equipment or generating electric power for this purpose. Where quantities surplus to mill requirements are available, bagasse is used by the sugar mills to generate additional electric power for supply to the grid. Small quantities are also used as industrial boiler fuel, primarily in the tea industry. This chapter examines these and other potential sources of future bagasse demand.

Industrial Process Heating

3.2 According to the Energy Assessment Report, the industrial sector accounts for about one-fifth of total commercial energy consumption in Mauritius. With the rapid growth of industries in the Export Processing Zone, this figure is expected to rise significantly in the coming decade. The major industrial consumers of fuel and diesel oils are the textile mills, the tea factories, the beverage industry and the edible oils refinery. According to data from a 1986 Industrial Energy Survey by the Ministry of Energy and Internal Communications (MEIC), the tea industry alone accounts for over one-third of industrial consumption of fuel oil.

Tea Industry

3.3 A priori, the tea industry is a relatively promising potential market for bagasse as a substitute for imported fuel because: (a) energy accounts for one-third to two-thirds of total operating costs; (b) bagasse is potentially less costly than oil per GJ; and (c) the oil-burning boilers currently used for raising heat to wither and dry tea can be converted to burn bagasse. The industry produces about 8,100 tons of tea per year, each ton of which requires 35 GJ of heat energy for withering and drying. According to an energy survey of the tea industry conducted by the MEIC in April 1986, it consumed 4,750 tons of fuel oil and 5 million kWh of electricity in 1985, costing US$1.8 million.

3.4 It is estimated that 15,600 tons of bagasse would be required to substitute fully for this quantity of fuel oil. With potential energy conservation and management improvements, international experience suggests that specific energy consumption could be reduced to as little as 20 GJ/ton or 162,000 GJ annually. This would require 2,700 tons of fuel oil, costing US$695,000, which could be substituted by 8,900 tons of bagasse.

3.5 Several tea factories have already identified potential savings from bagasse substitution and have converted their boilers accordingly. Given a reliable, competitive supply of bagasse, more of the industry might be prepared to make the required investments for the conversion of their fuel oil boilers to bagasse-fired boilers or heat gasifiers. To facilitate this process, Terms of Reference for recommended technical assistance to assess the costs and benefits of potential energy conservation and bagasse substitution investments in the tea industry are presented in Annex 7.

Other Industries

3.6 Other industries with fuel oil boilers, such as textiles, might also find bagasse substitution cost-effective. Their conversion costs would probably be higher than those of the tea industry, but the savings could still make the conversion economic. However, as no comprehensive, plant-by-plant information is available on industrial consumption of fuel oil in boilers, it is difficult to estimate potential industrial bagasse demand outside the tea industry. A detailed analysis of the least-cost approach to satisfying industrial energy needs is required. This would comprehensively define the economic potential for utilizing bagasse for heat and steam raising in industry.

Particleboard and Cellulose Products

3.7 Until recently, a factory located at the St. Antoine sugar mill, used surplus bagasse to produce particleboard. The plant's capacity was about 3,000 tons, at which it would consume 9,000 tons of bagasse. However, the potential market for particleboard in Mauritius was less than 1,000 tons/year and Mauritian supplies were not competitive in the nearest export market, Reunion. Output declined to 400 tons in 1985 and, in 1986, the factory ceased production.

3.8 Although bagasse is used in other countries to produce particleboard and other cellulose products, the small size of the Mauritian market and the island's distant location from potential major export markets make their manufacture uneconomic in Mauritius. Hence this is unlikely to become economic use for bagasse.

Household Fuel

3.9 Bagasse, in the form of briquettes, is technically a potential substitute household fuel for increasingly scarce firewood and charcoal. Based on data from a household energy survey published by the MEIC in July 1986, the Ministry of Agriculture's Forestry Department estimates household consumption of fuelwood (firewood and charcoal) at 48,000 tons/year. Fuelwood market prices are about US$15.6-18.5/ton

(US$1.70-2.00/GJ) for firewood and US$178-204/ton (US$6.80-7.80/GJ) for charcoal. It is estimated that bagasse briquettes could be sold for around US$2.00/GJ. However, no stove modification or consumer acceptability tests have been conducted with bagasse briquettes in Mauritian households. Further, the Government of Mauritius (GOM) has embarked on a program to promote LPG, not densified biomass, as a fuelwood substitute. Therefore, the household bagasse market can only be noted as an interesting possibility, not as a firm option, at this stage.

Power Generation

Current Bagasse Power Output

3.10 Fourteen sugar mills supplied a total of 103 GWh of power to the CEB in 1985 (Table 3.1). Fifty-eight GWh were generated from bagasse, the balance of 45 GWh from coal. Three sugar mills (FUEL, Medine and Mon Tresor) have relatively efficient condensing turbo-alternators. The FUEL plant has a rated capacity of 21.7 MW, Medine 10 MW and Mon Tresor 5 MW. FUEL is capable of burning either bagasse or coal; the other two plants, bagasse only. Due to the current limited supply of bagasse, FUEL is the only plant able to operate year-round. In 1985, FUEL supplied 75 GWh of power, Medine 13 GWh, and Mon Tresor 3 GWh.

3.11 The remaining 11 mills use small, inefficient back-pressure turbo-alternators to produce power for their own use and a small, variable surplus for sale to the CEB. These units run only during the crop season when the mills are in operation. Their supply of surplus power is not available year-round, fluctuates with mill operations, and is not susceptible to modulation by CEB. Hence it is of relatively low value and commands a very low price, which provides little incentive to expand power output and hence bagasse supply for power generation.

Table 3.1: POWER GENERATION BY THE SUGAR MILLS, 1985
(GWh)

Fuel	Station	Crop	Intercrop	Total
Bagasse	FUEL	30	--	30
	Medine	13	--	13
	Mon Tresor	3	--	3
	Others	12	--	12
Subtotal				58
Coal	FUEL	5	40	45
Total				103

Source: CEB.

Scope for Increasing Bagasse-fueled Generation

3.12 The highest-value use for bagasse in power generation is as fuel for the production of firm power. This can be achieved by: (a) displacing coal at the FUEL power station; (b) assuming Medine converts to dual coal/bagasse firing, substituting bagasse for coal there also; and (c) making the Mon Tresor/Mon Desert plant capable of firm, year-round power generation. Due to its age and small size (2.5 MW), coal conversion at Mon Tresor would probably not be economic. Therefore, to become a supplier of firm power, Mon Tresor would need sufficient bagasse for year-round operation. Over the longer term, assuming bagasse supply increased substantially, a fourth option would be construction of a new 10-20 MW bagasse-fueled power station. This should preferably have dual-fuel (bagase/coal) capability and be located at a sugar mill with a large bagasse surplus.

3.13 Based on a conservative assessment of potential generating plant performance, the year-round firm capacity of the three existing bagasse power plants is estimated to be: FUEL, 16 MW; Medine, 6 MW; and Mon Tresor, 2.5 MW. Assuming generation for 130 days in the crop period and 145 days in the intercrop at a 70% load factor, and allowing for normal operating problems, potential annual energy output is roughly 85 GWh from FUEL, 35 GWh from Medine and 16 GWh from Mon Tresor, a total of 136 GWh (Table 3.2).

Table 3.2: POTENTIAL FIRM CAPACITY AND ENERGY OUTPUT OF THE THREE BAGASSE-FIRED POWER STATIONS

Period	FUEL		Medine		Mon Tresor	
	Capacity	Energy	Capacity	Energy	Capacity	Energy
	(MW)	(GWh)	(MW)	(GWh)	(MW)	(GWh)
Crop	16	35	6	15	2.5	6
Intercrop	17	50	7	20	3.5	10
Year		85		35		16

Source: MSA and mission estimates.

3.14 Based on these potential power outputs and the use of 20% m.c. (stored) bagasse, the quantities of additional bagasse required by the three generating plants to operate year-round on bagasse are estimated to be 114,000 tons at FUEL, 56,000 tons at Medine, and 36,000 tons at Mon Tresor, a combined total of 206,000 tons per year (Table 3.3).

Table 3.3: ADDITIONAL BAGASSE SUPPLY REQUIRED FOR YEAR-ROUND POWER GENERATION AT EXISTING STATIONS

Parameter	Unit	Power Station		
		FUEL	Medine	Mon Tresor
Potential power output	GWh/yr	85	35	16
Bagasse-fired output, 1985	GWh	30	13	3
Shortfall of actual from potential	GWh/yr	55	22	13
Bagasse generation efficiency a/	kWh/ton	483	392	362
Additional bagasse required	'000 tons	114	56	36

a/ See para. 6.7 for derivation.

Source: CEB, MSA, Mission estimates.

The extent to which it will be economic to satisfy this potential demand for bagasse depends on its economic cost of supply, vis-a-vis alternative fuels, for power generation.

IV. POTENTIAL QUANTITY AND COST OF ADDITIONAL BAGASSE SUPPLY

Estimation Techniques

4.1 The potential quantity of surplus bagasse that could be saved by the sugar industry and supplied for other purposes is primarily a function of three parameters:

(a) the quantity of cane processed during the crop season;

(b) the fiber content of that cane; and

(c) the efficiency of bagasse utilization within the sugar mills to produce electricity and process steam for their own use.

4.2 Parameters (a) and (b) differ between mills and from year to year, but are simple to estimate from existing industry data. The actual level of parameter (c) is estimated most accurately by observation of mill steam and electricity consumption. However, this is a time-consuming and costly process, and subject to considerable measurement error. Consequently, theoretical calculations of energy use, based on known characteristics of mill plant and equipment, are often used for estimation purposes. The potential efficiency of bagasse use--after adjustments to bagasse feed and boiler settings and investments in more energy efficient plants and equipment--is established by simulating the energy requirements of alternative plant configurations.

Existing Analyses of Potential Bagasse Supply and Cost

4.3 Several different methodologies have been used to estimate mill bagasse requirements and potential economies therein in previous analyses of potential surplus bagasse supply and cost. A study by the Mauritius Sugar Authority (MSA) in 1985 estimated the additional bagasse surplus that would result if a sample of seven sugar factories reduced their steam consumption from its then current level to a target of 400 kg/ton of cane. Technically, the MSA considered 400 kg/ton a feasible target, and one which would require relatively modest investments. The resulting potential bagasse surplus was estimated to be 146,400 tons/year for the seven mills.

4.4 Estimates of potential bagasse supply presented in the Government's Action Plan for the Sugar Industry were based on an assumed mill own-use bagasse requirement of 18.5 tons of bagasse per 100 tons of cane processed. At 78% boiler efficiency, achievement of this target energy efficiency level was estimated to result in a bagasse surplus of 430,000 tons in an average (6 million ton) crop year. If average boiler efficiency was raised to 83%, the surplus would be about 500,000 tons.

In both these analyses, it was estimated that the potential bagasse surplus could be produced, handled, stored and transported at a cost competitive with the cheapest alternative fuel for power generation.

4.5 Unfortunately, both these estimation methodologies have severe practical limitations. The first is based on achieving an arbitrary target steam consumption level, unrelated to the specific energy-using characteristics of each sugar mill. Hence it may seriously understate or overstate the potential for cost-effective improvements in each mill's energy use. The second approach is still more arbitrary, in that it assumes the achievement of a "model" process steam requirement at each mill, which may or may not be cost-effective in terms of the mill's current process set-up, the relationship between its boiler capacity and steam consumption or the balance between high pressure and low pressure steam requirements. Both studies inadequately address the issue of bagasse handling and storage costs.

Mission Methodology for Estimating Potential Bagasse Savings

4.6 The mission's methodology was to base the calculation of potential mill bagasse savings and supply on the estimated energy requirements of each mill, based on its existing plant configuration, and analysis of the most cost-effective potential modifications to each mill that would reduce energy consumption and increase surplus bagasse availability.

4.7 The first step was to estimate current requirements for both high pressure steam for power generation and operation of the prime movers and low pressure steam for process heat. These requirements were compared with potential steam supply from the boilers to identify any potential excess of bagasse, relative to own-use energy needs. By definition, this potential supply requires no investment and has a zero cost, net of bagasse handling, storing and transportation to the user. In some cases, where the mill has a cost-effective use for surplus bagasse, part or all of this estimated potential surplus may be realized. In most cases, however, the surplus currently is of little value and its production imposes additional costs of bagasse disposal on the mill. In these cases, the potential "surplus" is eliminated.

4.8 Taking the existing configuration of each mill and its consequent energy requirements as datum, the second step was to simulate the effect of potential investments in more energy efficient plant and machinery on mill energy requirements. The investments which resulted in the largest net bagasse savings per dollar of expenditure were then costed, the resulting surplus bagasse estimated, and the unit cost of producing that surplus calculated. In order to maintain the balance between high pressure and low pressure steam, this process required several iterations. First, modifications to the process steam utilization system were simulated, for example, extensive vapour bleeding from the evaporator and quintuple-effect evaporator operation. Calculations were made in parallel of exhaust steam produced by the prime movers driving the cane preparation department, the milling department and the turboalternators. This figure was then compared with the process steam requirement, after modification, as outlined above. The modifications were costed and the net additional quantity of bagasse estimated.

4.9 Where the exhaust steam produced was in excess of process steam requirements, high pressure steam savings were identified: for example, higher efficiency mill drives and extraction/condensing turbo alternators to reduce electrical generation steam consumption. The cost of these investments was estimated and again expressed in terms of bagasse saved.

4.10 Having estimated the required boiler steam output after the above modifications, options for improving boiler efficiency were evaluated: for example, bagasse pre-drying using boiler flue gases, improved use of sugar factory condensates and improved boiler control systems. The cost was again estimated and compared with the excess bagasse derived from the modification.

4.11 As is evident, use of this methodology to estimate potential bagasse savings requires on-site analysis of each sugar mill. The mission was able to visit and fully analyze potential bagasse savings at 15 of the 19 existing sugar mills. A sixteenth mill (Beau Champ) preferred not to be visited. The three remaining mills (Rose Belle, St. Felix and Belle Ombre) are not considered to be significant potential sources of bagasse supply.

4.12 For projected mill cane throughput (parameter (a)), forecasts for the 1986 crop season were used. As the 1986 crop is large, this represents the upper limit of probable future cane throughput. Observed fiber content by mill for the initial weeks of the 1986 crop was used for parameter (b). Although fiber content varies from mill to mill, it is relatively stable from year to year. Use of a single point observation does not therefore introduce significant error into the calculation. The estimates are given in Table 4.1.

4.13 The forecast total of 5,050,000 tons of cane to be processed by the 15 mills for 1986 is equivalent to a crop of over 6 million tons for the island as a whole. This is close to the recent peak crop of 6.6 million tons in 1982 and above the 1975-85 average of roughly 6 million tons. The low point of recent throughput was 1975, with a total of 4.3 million tons. On average, cane quantity processed per year will be less than that of 1986, and, in extremely low years, could fall to as little as 65% of this figure.

Table 4.1: ESTIMATED 1986 CANE QUANTITIES PROCESSED AND FIBER CONTENT BY MILL

Sugar Mill	Cane Processed	Fiber Content
	('000 tons/year)	(%)
FUEL	700	12.94
Constance	310	14.50
Medine	500	14.04
Beau Plan	300	15.52
Belle Vue	450	15.19
Mon Desert/Alma	360	13.00
Mon Tresor/Mon Desert	280	13.89
Soc. Suc. Riv. Remp.	310	14.65
Riche en Eau	275	13.20
Mount	235	15.04
Brittania	225	12.37
Savannah	310	13.34
Highlands	275	11.98
St. Antoine	270	13.39
Union St. Aubin	250	15.60
Total	5,050	

Source: Mission estimates.

4.14 The mision's analysis of potential mill-modification investments attributes the full cost of each investment to the resulting incremental saving of bagasse. In many cases, this assumption is realistic, in that potential bagasse savings will be the sole or primary incentive for the investment. Where other benefits result, such as improved sugar quality or higher output, it is appropriate to attribute part of the cost of the investment to those benefits. This assessment must be left to the individual mills. It will have the effect of reducing the unit cost of the affected bagasse saving in proportion to the relative value of the other benefits.

Estimates of Potential Bagasse Savings

4.15 Estimates of the potential quantities of bagasse that would be saved at each mill, and their investment cost per ton of bagasse saved, are set out in Annex 1 and summarized by a range of investment costs in Table 4.2. The costs cover only those investments associated with bagasse saving. They exclude costs of bagasse handling, storage and transportation, associated with supply of bagasse to a potential customer. These latter are specific to the purpose for which the bagasse is used, the quantities required and the location of the supplier and consumer. They are estimated in the following two chapters for the purpose of power generation.

Table 4.2: POTENTIAL BAGASSE SAVINGS AND ASSOCIATED INVESTMENT COSTS
('000 tons/year)

Sugar Mill	Surplus Available Without Investment a/	Incremental Quantities of Bagasse by Cost of Mill Investment in Bagasse Saving			
		Under $5/ton	$5-9.9/ton	$10-14.9/ton	$15/ton and Over
FUEL b/	--	--	--	--	14.2
Medine b/	--	--	--	--	11.8
Constance	18.7	--	--	--	12.6
Beau Plan	16.9	--	--	--	10.2
Belle Vue	25.2	5.5	--	--	7.3
Mon Desert	--	--	19.2	--	5.5
Mon Tresor b/	6.5	3.5	--	--	6.1
S. S. Riv. Ramp.	11.3	10.1	--	--	4.9
Riche en Eau	--	--	--	16.8	7.5
Mount	--	--	--	--	24.0
Savannah	--	--	23.9	--	9.9
Highlands	--	--	--	--	18.6
St. Antoine	11.9	--	--	10.9	10.4
Union St. Aubin	12.9	--	4.4	--	3.9
Total	103.4	19.1	47.5	35.2	155.1
Cumulative		122.5	170.0	205.2	360.3

a/ Quantity of bagasse from cane minus current own-use requirements. Due to limited bagasse market and disposal problems, this surplus is not necessarily realized.
b/ Excluding bagasse currently used for power generation.
Note: Amounts of less than 1,000 tons are excluded because of their limited economic significance.

Source: Mission estimates.

4.16 Summary conclusions as to potential bagasse savings and their associated costs are:

(a) 103,400 tons of bagasse, surplus to mill own requirements, can be saved simply by reducing own-use and without investment in mill modifications;

(b) an additional 19,100 tons can be saved at an investment cost of less than Rs 65 (US$5) per ton, and a further 47,000 tons at a cost of less than Rs 130 (US$10) per ton; and

(c) at least 360,000 tons of surplus bagasse can be saved if all the identified investments are implemented. 3/ Of this total, 190,000 tons (over 50%) will cost more than Rs 130 (US$10) per ton to save.

4.17 Previous analyses of potential bagasse supply and cost, such as those briefly described in paras. 4.4-4.6 above, estimated the average cost of potential bagasse savings to range from Rs 50-100/ton ($3.70-7.40/ton). The mission's analysis suggests that about 135,000 tons of bagasse could be saved at the 15 mills at a cost of $3.40/ton or less. Total potential savings at a cost of $7.40/ton or less are about 225,000 tons. These totals are substantially below previous estimates.

Ranking of Investments to Increase Bagasse Savings

4.18 For each mill, the mission identified at least two investment packages that would increase the quantity of bagasse saved. Their content, capital, and operating costs are summarized in Annex 2. The selection was based on analysis of each mill's current energy requirements and of alternative cost-effective modifications thereto. The most cost-effective investments, in terms of additional bagasse savings, were generally improvements in the efficiency of process steam use. In some cases, these must be matched by complementary reductions in high pressure steam consumption, generally by replacing steam-driven engines and pumps with electric motors. The potential mill investments that would result in bagasse savings costing less than Rs 130/ton (US$10/ton) are presented in Table 4.3. Their combined cost is Rs 18.8 million (US$1.4 million).

4.19 The installation of bagasse dryers to pre-dry bagasse with boiler flue gases prior to burning was an option evaluated for each sugar mill. This would reduce the moisture content of the bagasse from an average of 50% to 35% and increase combustion efficiency. At an average capital expenditure of $890,000 per mill, the investment would cost between $17-61/ton of bagasse saved, depending on the characteristics of the mill concerned. Because the sole rationale for this investment would be to reduce own-use of bagasse, it is appropriate to allocate its full cost to the quantity of bagasse saved. At a cost of US$17/ton of bagasse

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3/ The potential savings of bagasse could be increased further by the replacing existing boilers with new high-pressure boilers at several mills. This investment, together with complementary plant changes, was analyzed for The Mount. It was estimated to cost US$37.43/ton of bagasse, if the cost was fully attributed to the incremental quantity of bagasse saved. Although uneconomic on grounds of bagasse saving alone, boiler replacement could be justified if it produces other benefits.

or higher, such investments would not be viable, except perhaps at FUEL, if costly bagasse handling was not required.

Table 4.3: POTENTIAL MILL INVESTMENTS
COSTING LESS THAN US$10 PER TON OF BAGASSE SAVED a/

Mill	Nature of Investment	Capital Cost	Cost of Bagasse	Quantity of Bagasse) b/
		(US$)	(US$/ton)	(tons/year)
Mon Tresor/ Mon Desert	150 m^2 juice heater	45,801	2.54	3,500
Belle Vue	900 kw multistage turbin3e to drive 1st and 2nd mills 85m^2 juice heater	100,954	4.35	5,500
Mon Desert/ Alma	Conversion to quintuple-effect evaporation with addition of one 600m^2 body and one 900m^2 body. 135m^2 juice heater.	378,782	5.08	14,100
Union St. Aubin	Conversion to quintuple-effect evaporation with addition of new 400m^2 body and operation of effects 2 and 3 in parallel. 225m^2 juice heater.	152,717	6.72	14,100
Savannah	Conversion to quintuple-effect evaporation with addition of 900m^2 body. 220m^2 juice heater. 1000 kV condensing turbo alternator Electric motor to replace ID fan steam drive.	715,065	7.02	23,300
Total		1,393,319		60,500

a/ Assuming cost of the investment is fully attributed to incremental bagasse production.

b/ Rounded to the nearest 100 tons.

Source: Mission estimates.

4.20 Whether investments in bagasse saving are economic will depend on the delivered cost of bagasse to the customer, relative to the cost of alternative fuels. That cost will be use- and consumer-specific, and will include the costs of bagasse handling, storage and transport. Because by far the most significant proven demand for bagasse is as a fuel for power generation, the next chapter evaluates the cost of alternative bulk bagasse handling systems for this purpose. The following chapter then estimates, based on the total cost of bagasse saving, handling, storage and transport, the quantities and sources of potential bagasse supply that could be competitive for power generation.

V. ANALYSIS OF ALTERNATIVE BAGASSE HANDLING SYSTEMS

Evaluation Criteria

5.1 Four bagasse handling systems--loose piling, pelletizing, briquetting and baling--were assessed in terms of their cost-effectiveness for bulk bagasse supply for electric power generation. Overall, the preferred handling system should:

(a) provide year-round supply of a uniform fuel to the major users;

(b) be based on an easily-managed technology that is compatible with sugar mill operations and is flexible with regard to bagasse output;

(c) be designed to minimize storage losses and risks of pollution, fire, and to health; and

(d) be flexible with regard to scheduling, so that phased implementation is possible.

These criteria are used to assess the various bagasse handling options which potentially could be applied in Mauritius.

Description of Alternative Bagasse Handling Systems

Loose Bagasse

5.2 Loose piling of bulk bagasse is used almost exclusively for wet bagasse production processes, such as pulp and paper manufacturing or hardboard production. After separation of the pith from the fiber by means of depithing machines, the fibers are pumped onto piles as slurry. The continuous flow of liquid allows for fermentation control, which is important for limiting losses from biodegradation. The temperatures inside the piles are monitored periodically and slurry is poured on spots where excessive heat increases have been detected. In some cases, the liquid contains chemicals to increase the "softening" of the fibers. Bulldozers are sometimes used to distribute and compact the fibers.

5.3 Piling of loose, undepithed bagasse in large quantities is rarely practiced for dry process use, such as boiler-firing. Its technical, environmental and economical disadvantages for such use are:

(a) Storage Losses--with no means of controlling the degree of fermentation and the development of heat inside loose, dry piles, high deterioration losses can occur. Also, the risk of spontaneous combustion inside the piles is high;

(b) High Handling Costs and Losses--because of loose bagasse's low bulk density, large storage areas and transport in enclosed trucks are required. This, in turn, entails high costs for piling, reclaiming, loading and unloading, plus handling losses estimated at over 10%;

(c) Health Hazards--with a dry product, there is excessive formation of dust during handling, storage and transport. This fermented dust is a severe health hazard, causing bagasosis; and

(d) Unpredictable Fuel--because the moisture content of loose-piled bagasse varies according to weather conditions and the degree of fermentation, its calorific value cannot be predicted.

Thus, on technical, cost, and health grounds, loose piling of bagasse is not recommended as a bulk handling option.

Pelletizing

5.4 Pelletization is a high-pressure densification process which requires that bagasse be dried to a moisture content of 10-12% before being fed to the pelletizer. To date, this method has been in three locations: at the Theo Davis mill in Hawaii, USA; at the Beau Champ mill in Mauritius; and at three plants in Cuba. The Hawaiian plant has been closed, the plant in Mauritius has ceased production and the Cuban facilities are at the commissioning stage.

5.5 Pelletization has a number of disadvantages for bagasse handling:

(a) High Costs - capital and operating costs per GJ of output are high, relative to other options, because of costly drying equipment, energy, spare parts and control expenses;

(b) Die Wear - wear on dies has been higher than expected due to the abrasive character of bagasse;

(c) Difficult Management - the drying and pelletizing process is highly sensitive to fluctuations in sugar mill operation (e.g., flue gas temperature and volume, bagasse flow, etc.). Even with elaborate control equipment, it is difficult to keep these operational parameters within strict limits and thus to achieve a smooth operation; and

(d) Fire Hazard - unless pellets are properly cooled prior to storage, they can present a fire hazard.

For these reasons, past experiments with bagasse pelletization have not been satisfactory.

5.6 However, pellets have several advantages, including a high bulk density (600 kg/cubic meter), which reduces storage and transport costs. Further, they are a uniform product with a low moisture content. This means that their energy value is predictable, they are an easy-to-handle fuel, and they experience little fermentation (if stored under cover). Therefore, pelletization merits further analysis as a potential handling option.

Briquetting

5.7 Briquetting is another high-pressure densification process which produces log-like cylinders of 15-90 mm diameter from 10-12% m.c. bagasse. This method has been adopted in several facilities world-wide for processing bagasse, although none of these plants is apparently still in operation. Either the sugar mill has closed or the users have changed their fuel requirements or ceased operating. However, the World Bank is financing a pilot bagasse and cane-top briquetting facility in Ethiopia, due for commissioning in 1988.

5.8 Specific experience with bagasse briquettes includes:

(a) a sugar mill in the Dominican Republic to supply briquettes to a board mill which never began operation;

(b) three sugar mills in Puerto Rico to produce briquettes for board and paper mills;

(c) one mill in the Philippines to produce fuel briquettes during the intercrop season at the sugar mill; and

(d) a mill in Guadeloupe to produce briquettes for the adjacent board factory.

An attempt was also made in Mauritius about eight years ago to produce briquettes for local lime kilns. A plant was installed at the Savannah sugar mill, but its drying and feeding systems were poorly designed and it never entered full-scale commercial operation. The equipment was abandoned after several attempts to operate the system.

5.9 Some of the disadvantages of pelletizing also apply to briquetting, including:

(a) Large Investment--although somewhat less than pelletizing plants, the capital requirements of briquetting systems are substantial;

(b) Power Consumption and Die Wear--these are also less than for pellets, due to the larger circumference and sectional area of briquettes. However, power consumption is still high, especially for drying; and

(c) High User Costs--for use in existing mill boilers, briquettes have to be crushed prior to burning.

5.10 Similarly, briquettes have many of the advantages of pellets, namely high bulk density, uniform condition, low moisture content and low fire risk. For these reasons, briquetting is a technically feasible handling option for bagasse in Mauritius.

Baling

5.11 Baling is the most common method used around the world to handle, store and transport large quantities of bagasse for dry process uses such as power generation. Currently, all the sugar mills in Mauritius produce small bagasse bales (70-80 kg at 50% m.c.) for start-up at the beginning of the season and for emergency or routine shutdowns during the season. Altogether, 10,000-20,000 tons of such bales are produced annually. Surplus bales are sold to certain tea factories for use in their boilers.

5.12 The major drawbacks of the baling method, along with possibilities for reducing these disadvantages, are:

(a) Storage Losses--excessive fermentation losses can occur if the bales are not stored in a way that promotes drying, i.e., with gaps between the bale stacks to permit air circulation. Pre-drying or chemical treatment of bagasse reduces the risk of such exothermic decomposition.

(b) Fire Hazard--losses due to fire can occur since dry bagasse is highly flammable. To counteract this, an appropriate fire suppression system is required. Bales need to be stacked in stand-alone piles with sufficient space to allow for isolation of a burning pile and wetting of surrounding stacks. A net of water pipes and hoses for fire-fighting must be provided for this purpose.

(c) High Materials Cost--significant costs can be incurred for baling wire, particularly if a large number of bales have to be handled. These can be reduced by increasing the size of the bales.

(d) Cost of Mechanization--when large quantities of bagasse are involved, handling must be mechanized. Again, this is cheaper when larger bales are produced.

5.13 The principal advantages of baling bagasse are:

(a) use of a familiar, easily managed technology that is compatible with sugar mill operations and is flexible with regard to throughput;

(b) relatively modest investment requirements, compared with pelletizing and briquetting;

(c) less dust formation during handling and storage and greater potential for fire control, compared with piling loose bagasse; and

(d) possibility of mechanized handling and transport in existing sugar trucks without further modification.

Bale Size Considerations

5.14 Potential bagasse bale sizes range from 30 kg (very small), through 70-80 kg (small), to 650 kg (large). Manual handling requires very small bales of no more than 30 kg. The disadvantages of such very small bales are their high costs, due to the large number of bales that must be handled--about 400 per hour for a mill producing 20,000 tonnes of surplus bagasse per year--and their high consumption of binding wire.

5.15 Moving up size range to 70-80 kg bales and into mechanized handling, processing of 20,000 tonnes of surplus bagasse per year still requires handling nearly 200 bales per hour, or one bale every 20 seconds. This again makes mechanization expensive and difficult to manage.

5.16 In comparison, large bales (650 kg), have several advantages. Less binding wire is required and handling losses are lower. Furthermore, the power consumption to break large bales is substantially smaller than for small bales, since large bales can be fed into a bale-breaker in a steadier flow and under better, automatically controlled conditions. Finally, removal of binding wires is more reliable since large bales always lie the same way on a feeding conveyor, leaving the wires always in the same position and hence easier to locate and remove. Large bales are thus more economic than small bales for handling bagasse in bulk quantities.

5.17 The economic advantages of large baling are confirmed by its use in more than 10 sugar mills in Latin America and Africa. One of these mills uses a variant of the system known as Bagatex 20. This uses a chemical catalyst to accelerate and stabilize bagasse drying and covered storage of the baled bagasse. A brief description of the process is given in Annex 4.

Comparative Cost of Alternative Bagasse Handling Systems

5.18 In view of its operational shortcomings and evident health risks, the option of loose handling bulk bagasse is rejected as unfeasible. Detailed cost estimates of the other three potential systems--pelletizing, briquetting and large baling--are set out in Annex 2. All three systems were sized to handle a larger volume of bagasse than is likely to be economically competitive, but the same bagasse throughput was assumed for each system. Hence, a smaller throughput of bagasse will not materially alter their comparative cost. Bagasse transportation is assumed to be by Mack-type sugar trucks, at an average cost of US$0.166/ton kilometer. The assumptions used in estimating transport costs for each handing option are set out in Annex 3.

5.19 Large bales were found to be by far the least-cost handling option, costing $13.91/ton of bagasse. Briquetting would cost $31.46/ton and pelletizing $41.12/ton (Table 5.1).

Table 5.1: SUMMARY COSTS OF ALTERNATIVE BAGASSE HANDLING SYSTEMS ($/ton)

Cost Component	System		
	Pelletizing	Briquetting	Large Baling
I. Pre-drying and processing			
A. Capital	21.90	11.29	1.30
B. Labor	9.01	6.92	2.52
Subtotal	30.91	18.21	3.82
II. Storage			
A. Capital	5.14	6.15	2.50
B. Operating	1.67	1.85	3.16
Subtotal	6.81	8.00	5.66
III. Transport	3.40	3.40	3.40
IV. Crushing/bale breaking			
A. Capital	0.00	0.74	0.43
B. Operating	0.00	1.16	0.59
Subtotal	0.00	1.90	1.02
Total	41.12	31.51	13.90

Source: Mission estimates.

5.20 More relevant for assessing the costs of the alternative bagasse handling systems is their comparative cost per unit of useful energy. On this basis, baling is again by far the least-cost option costing $1.05/GJ, compared with $2.06/GJ for briquetting and $2.69/GJ for pelletizing. The comparison is summarized in Table 5.2.

Table 5.2: COST OF ALTERNATIVE BAGASSE HANDLING SYSTEMS IN TERMS OF USEFUL ENERGY

Handling System	Moisture Content	Net Heating Value	Cost on Energy Basis
	(%)	(GJ/ton)	($/GJ)
Pelletizing	10	15.30	2.69
Briquetting	10	15.30	2.06
Large Baling	20	13.30	1.05

Source: MSA and mission estimates.

VI. BAGASSE POWER POTENTIAL, 1987-2000

Introduction

6.1 As discussed above, the highest-value potential use for surplus bagasse is as a fuel oil substitute in industry. The tea industry, which already makes limited use of bagasse, is the most promising market, although the extent of this potential has yet to be confirmed. However, even total conversion of this industry to the use of bagasse would, after accounting for potential energy efficiency improvements, create demand for less than 10,000 tons of bagasse per year. This represents less than 10% of the bagasse savings that can be realized without investment in mill modifications and a much smaller fraction of potential supply. Increased use of bagasse in power generation, where existing facilities can utilize over 200,000 tons, is therefore clearly the major bagasse utilization option.

Benefits of Increased Bagasse Use

6.2 From an economic efficiency standpoint, bagasse should be utilized for power generation up to the point at which the marginal cost of bagasse-based power equals the value of the resources saved from producing that marginal unit. If bagasse-based power adds firm generating capacity to the CEB system, it should be valued at the cost of alternative generation saved, since its production would permit, at the margin, the deferral of investment in and operation of new generating plant. If it substitutes for an alternative fuel, the bagasse should be valued at the economic cost of the fuel replaced.

6.3 In the case of Mauritius, the FUEL bagasse/coal generating plant is already a source of firm power capacity. Substitution of bagasse for coal at this plant would not add to firm power capacity and should not be so valued. Assuming Medine converts to dual bagasse/coal firing, it too will become part of firm power capacity and the same condition applies. Should additional bagasse supply permit the bagasse-fired power plant at Mon Tresor/Mon Desert to operate year-round, and its capacity be considered firm by CEB, it should be valued at the cost of alternative generation saved.

6.4 Ideally, the value of alternative generation saved is derived from a least cost expansion plan for the power system. In the case of Mauritius, the least cost expansion plan is being prepared and this report is one input. Therefore, an assumption must be made as to the likely value of alternative generation saved. For this purpose, the value of Rs 0.78/kWh is used, the estimated cost of four-stroke diesel generation.

6.5 In the case of fuel substitution, the alternative generating fuel at the sugar mill generating stations is coal. Its economic cost of supply to FUEL in mid-1986 was Rs 950 ($70.4)/ton. Assuming generation of 1400 kWh/ton of coal produces the base-case values for alternative generation and fuel substitution savings shown in Table 6.1.

Table 6.1: ASSUMED VALUE OF BAGASSE GENERATION AND FUEL REPLACEMENT SAVINGS PER KWH

Currency	Capacity	Fuel Replacement
Mauritius rupees	0.78	0.68
U.S. dollars	0.06	0.05

Source: Mission estimates.

Potential Economic Supply of Bagasse for Power Generation

Estimation Methodology

6.6 The generating efficiency (kWh per ton of bagasse), and location of the three existing bagasse-fired power stations (FUEL, Medine and Mon Tresor) are different. Hence, a plant-specific maximum economic delivered cost of bagasse power, up to which its use as a generating fuel is justified, must be estimated for each station. The methodology used to determine that maximum delivered economic cost is as follows:

(a) determine the average kilowatt hours per ton of bagasse achievable at each generation site;

(b) value this power, in the case of FUEL and Medine, by the economic cost of coal saved; in the case of Mon Tresor, by the cost of alternative generation; and

(c) deduct the costs of bagasse receiving, storage, bale breaking and boiler feeding at the power station.

6.7 Parameter (a), kWh generated per ton of bagasse supplied, is estimated for 20% m.c. bagasse bales, based on their weight at the time of production. This assumes that the bales are produced either by the Bagatex 20 process or air dried to reduce their moisture content to that level. At the time of production, a 650 kg bale of 50% m.c. bagasse has a heating value of 1,790 kcal/kg. After drying to 20% m.c., it weighs approximatley 370 kg and has a heating value of 3,250 kcal/kg. Using the formula:

$$PO_{20} = PO_{50} \times \frac{HV_{20} \times Wt_{20}}{HV_{50} \times Wt_{50}}$$

where PO_{20} = power output (kWh/ton) of 20% m.c. bagasse
PO_{50} = power output of 50% m.c. bagasse
HV_{20} = heating value (kcal) of 20% m.c. bagasse
HV_{50} = heating value of 50% m.c. bagasse
Wt_{20} = weight of 20% m.c. bagasse bale
Wt_{50} = initial weight of 50% m.c. bagasse bale

and solving for PO_{50} = 431 kWh/ton at FUEL
350 kWh/ton at Medine
323 kWh/ton at Mon Tresor

estimated power output per ton of bagasse at each generating plant is as shown in Table 6.2:

Table 6.2: POWER OUTPUT FROM BAGASSE AT POWER PLANTS
(kWh/ton)

Plant	Power Output
FUEL	483
Medine	392
Mon Tresor	362

Source: Mission estimates

6.8 Parameter (b), the value of additional bagasse-based power, is estimated for FUEL and Medine by multiplying the economic cost (per kWh) of coal saved by the kWh generated per ton of bagasse. In the case of Mon Tresor, it is estimated by multiplying the economic cost of alternative generation by the kWh generated per ton of bagasse. Parameter (c), the cost to the power plants of bagasse receiving, storage, bale breaking and fuel feeding, will vary with the throughput of bagasse, but is a small proportion of the total cost of bagasse power. A figure of Rs 0.14/kWh, derived from the estimated costs of a bagasse bale-handling facility at FUEL (see Chapter VII), is used to estimate this item.

6.9 Based on these parameters, the maximum economic delivered cost of bagasse for power generation, on coal substitution basis, is estimated to be Rs 314/ton (US$23.3/ton) at FUEL and Rs 253/ton (US$18.2/ton) at Medine. The maximum economic delivered cost of bagasse at Mon Tresor, valued at the cost of generation saved, is Rs 268/ton (US$19.9/ton). The derivation of these estimates is shown in Table 6.3.

Table 6.3: DERIVATION OF THE MAXIMUM COMPETITIVE COST OF BAGASSE AT THE EXISTING GENERATING STATIONS

Estimation Parameter	Unit	Plant: FUEL	Medine	Mon Tresor
1. Power output from bagasse	kWh/ton	483	392	362
2. Value at (a) Rs 0.68/kWh	Rs/ton	328	267	n.a.
(b) Rs 0.78/kWh	Rs/ton	n.a.	n.a.	282
3. Bagasse receiving cost	Rs/ton	-14	-14	-14
4. Maximum economic cost of bagasse (2-3)	Rs/ton	314	253	268
5. Maximum economic cost	US$/ton	23.3	18.7	19.9

Source: MSA, CEB, and mission estimates.

6.10 The quantities of surplus bagasse that can be saved by the sugar mills, and the cost of the necessary investments in mill modification, were estimated in Chapter IV. To estimate the quantities of bagasse that can be supplied economically to the bagasse generating stations, the potential bagasse suppliers' handling and storage costs and the cost of transportation to the generating plant must be added to the cost of bagasse saving. The resulting total cost of delivered bagasse from each potential supply source is then compared with the economic value of bagasse on a coal substitution and/or generation saving basis to determine the level of economically-justified bagasee use.

6.11 The unit (per ton) cost of bagasse baling and storage will vary from mill to mill, depending on the volume of bagasse available, location of the bale storage facility, etc. The average cost of large bale production and storage is $9.42/ton (Table 5.1, cost components I and II), based on an average throughput of 26,000 tons per mill. Of this total cost, 40% are capital and 60% are operating costs. This cost is used to estimate bagasse handling and storage per ton for each potential supplier. Capital costs are treated as fixed and allocated over the tonnage handled. Operating costs are treated as variable in proportion to the tonnage of bagasse handled. 4/

4/ For example, the costs of handling and storing 20,000 tons or bagasse are estimated as $9.48 x (0.4 x 26,000/20,000) (capital cost) + $9.48 x 0.6 (operating cost) = $10.62 per ton.

Economic Supply of Bagasse to FUEL and Medine at Mid-1986 Coal Costs

6.12 Based on the mission's estimates of the total cost of bagasse saving, baling, storage and transport, it is concluded that:

> FUEL can obtain 126,700 tons of bagasse at an economic cost less than its 1986 coal substitution value. Six mills could supply 112,500 tons and FUEL itself could supply 14,200 tons (Table 6.4).
>
> Medine can obtain 63,500 tons of bagasse at a cost less than its 1986 coal substitution value, but only by diverting supplies from FUEL, where the bagasse has greater economic value, due to FUEL's higher generating efficiency and location (Table 6.5). This bagasse should be used at FUEL, so Medine has no economic source of supply.

Table 6.4: ECONOMIC SUPPLY OF BAGASSE TO FUEL ON A COAL REPLACEMENT BASIS
(coal replacement value of bagasse US$23.3/ton)

Potential Suppliers	Bagasse Saving Cost	Handling Cost	Transport Cost	Total Cost	Quantity
	($/ton)	($/ton)	($/ton)	($/ton)	('000 tons)
Constance	0	11.0	1.2	12.2	18.7
Soc. Suc. Riv. Remp.	0	10.3	2.8	13.1	11.3
Belle Vue	0	8.9	4.7	13.6	25.2
Soc. Suc. Riv. Remp.	1.7	10.3	2.8	14.8	10.1
Beau Plan	0	11.6	3.7	15.3	16.9
Blle Vue	4.4	8.9	4.7	18.0	5.5
St. Antoine	0	14.0	5.0	19.0	11.9
FUEL a/	20.1	0	0	20.1	14.2
Union St. Aubin	0	13.3	8.3	21.6	12.9
Total					126.7

a/ Assuming the additional bagasse is burnt during crop season and no handling or storage costs are incurred.

Table 6.5: ECONOMIC SUPPLY OF BAGASSE TO MEDINE ON A COAL REPLACMENT BASIS
(coal replacement value of bagasse US$18.7/ton)

	Bagasse Saving Cost	Handling Cost	Transport Cost	Total	Quantity
	($/ton)	($/ton)	($/ton)	($/ton)	('000 tons)
Belle Vue	0	8.9	5.6	14.5	25.2
Beau Plan	0	11.6	4.8	16.4	16.9
Soc. Suc. Riv. Remp	0	10.3	6.6	16.9	11.3
Soc. Suc. Riv. Remp	1.7	10.3	6.6	18.6	10.1
Total					63.5

Sensitivity to Higher and Lower Coal Costs

6.13 The quantity of bagasse that can be supplied economically as a substitute fuel for coal in power generation at FUEL and Medine is dependent on the economic cost of coal. Should this rise, additional quantities of bagasse could become competitive for power generation. Should it fall, the converse could be true.

6.14 The World Bank forecasts that the real c.i.f cost of coal to Mauritius will fall by about 33% between 1985 and 1990, and then rise by 20% through 1995. A reported fall in the c.i.f. cost of coal imports from Rs 750/ton to Rs 616/ton in late 1986 is apparent evidence of the forecast initial decline in progress. For the purpose of power system planning, it is the long-term expected trend in coal prices that is relevant. Two coal price scenarios were used to test the potential impact on the economic supply of bagasse for power generation of alternative coal prices: a 20% rise and a 20% fall in the c.i.f. cost of coal, relative to its Rs 750/ton c.i.f. cost at the time of the mission. A 20% rise in the c.i.f cost of coal has no practical impact on economic bagasse supply to FUEL, which is all sufficient to displace coal at the lower coal price. At Medine, it would make the substitution of coal by 19,200 tons of bagasse from Mon Desert/Alma economic. A 20% fall in the c.i.f. cost of coal has no impact on bagasse use at Medine, which is using only its own supply. However, it does make potential bagasse supply to FUEL from Union St. Aubin (12,900 tons) and FUEL itself (14,200 tons) uneconomic.

Potential for Additional Firm Bagasse Power Capacity

6.15 FUEL is already a supplier of firm power. Assuming Medine converts to dual coal/bagasse firing, it too will become a source of firm power supply. The value of this power to the CEB is the avoided cost of alternative generation. This cost is estimated as Rs 0.78/kWh for four-stroke diesels. The correct pricing signals will be given to existing and potential firm power suppliers in the sugar industry, including FUEL and Medine, if firm power from them is priced by the CEB on this basis.

6.16 Mon Tresor/Mon Desert therefore offers the only potential to convert existing non-firm bagasse power capacity into firm capacity through the supply of additional bagasse. Assuming this plant is sufficiently reliable to be rated as a source of firm power, its output would be valued at the cost of alternative power generation, which again is Rs 0.78/kWh (US$0.06/kWh). The equivalent maximum economic cost of bagasse supply to Mon Tresor is Rs 268/ton (US$19.9/ton). For less than this cost, 43,300 tons of bagasse could be supplied which is more than sufficient to satisfy the plant's need for year-round operation (Table 6.6).

6.17 However, due to its age, small size, and questionable reliability, the Mon Tressor/Mon Desert plant is unlikely to be rated a supplier of firm power. In that event, year-round bagasse-fired generation would not be economic. The alternative of part-year operation would be economic only if additional power from Mon Tresor/Mon Desert was priced at a level that made the supply of bagasse costing over US$17/ton economic. That would require a price for power in excess of Rs 0.68/kWh.

Table 6.6: ECONOMIC SUPPLY OF BAGASSE TO MON TRESOR/ MON DESERT ON AN ALTERNATIVE GENERATION BASIS (Alternative generation value of bagasse US$19.9/ton)

Potential Suppliers	Bagasse Saving Cost	Handling Cost	Transport Cost	Total Cost	Quantity
	($/ton)	($/ton)	($/ton)	($/ton)	('000 tons)
Savannah	7.0	8.1	2.0	17.1	23.9
Union St. Aubin	0	15.1	3.8	18.9	12.9
Mon Tresor	0	19.5 a/	0	19.5	6.5
Total					43.3

a/ This cost could probably be reduced by use of a less capital-intensive baling system for these smaller tonnages.

Source: Mission estimates.

Potential Bagasse Power Generation from Existing Plants

Quantity

6.18 The highest-value use for additional supplies of bagasse for power generation is to replace coal at FUEL. At mid-1986 coal prices, sufficient bagasse can be delivered to FUEL, at a cost competitive with coal, to fully substitute for that fuel. This would raise FUEL's bagasse-fired generation from about 30 GWh in 1985 to its year-round potential of about 85 GWh, a net increase of 55 GWh. A 20% fall in the c.i.f. cost of coal would reduce the economic supply of bagasse to FUEL by 27,000 tons and additional bagasse-fired generation to 48 GWh.

6.19 At mid-1986 coal costs, there are no economic sources of additional bagasse supply to Medine. However, a rise of less than 10% in the c.i.f. cost of coal would make 19,200 tons of bagasse from Mon Desert/Alma competitive. This would result in an additional 7.5 GWh of bagasse power generation from this plant.

6.20 If rated a supplier of firm power, and its power output so valued, the potential supply of bagasse is sufficient for Mon Tresor/Mon Desert to operate year-round. This would add 2.5 MW to power capacity in Mauritius and result in about 16 GWh per year of additional bagasse power supply. As stated above, it is not considered likely that this condition can be met. In view of Mon Tresor/Mon Desert's relatively low generating efficiency, additional part-year generation is also unlikely to be economic. A summary of potential additional bagasse power generation from all three stations is presented in Table 6.7.

Table 6.7 ECONOMIC POTENTIAL FOR ADDITIONAL BAGASSE POWER GENERATION (GWh)

Plant	Economic Cost of Coal		
	$59.3/ton	$70.4/ton	$81.5/ton
FUEL	48	55	55
Medine	0	0	7.5
Total	48	55	62.5

Source: Mission estimates.

Timing

6.21 Only two of the least-cost potential suppliers of bagasse to FUEL--Belle Vue and Societe Sucriere de Riviere du Rempart--must invest in mill modifications to realize their potential economic bagasse savings. 75% of the potential economic savings (84,000 out of 113,800 tons) 4/ require only that the mills adjust their plant operation methods to maximize the output of surplus bagasse. However, all potential bagasse suppliers must invest in bulk bagasse handling and storage facilities. Capital costs for handling and storage would total about US$3 million for the five economic suppliers combined. Capital cost of the FUEL receiving facility would be about $0.3 million. Transport is assumed to be by existing sugar trucks, which could be leased on a short-term basis or operated during the intercrop period. The mill's willingness to invest in the necessary bagasse handling and storage facilities will therefore be the key determinant of the quantity and timing of additional bagasse supply.

6.22 Two major factors will determine this. One is the operating cost and reliability of the recommended large baling technique. The other is the price the mills expect to realize from the sale of bagasse. The second issue is addressed in the next section. As to the first, the Mauritian sugar industry is unfamiliar with the large-baling technique. Consequently, a project to construct a full-scale

4/ Assuming supplies are not required for Union St. Aubin.

demonstration baling and storage facility at the Constance sugar mill and a complementary bale-breaking and bagasse feed system at FUEL is recommended to familiarize the industry with the large-bale handling system. The recommended demonstration project is outlined in the next chapter. Should this recommendation be accepted, and assuming installation of the demonstration facility began during the 1987/88 intercrop period, it could be fully operational by 1990. This would add 8 GWh to bagasse power output in that year. Assuming the facility was successful, it could be replicated by the other mills during the 1991/2 intercrop period. FUEL would then be able to obtain sufficient bagasse to generate power year-round in 1992. Increased use of bagasse at Medine would be dependent on a rise in the economic cost of coal.

Bagasse Power Pricing Issues

Power Pricing

6.23 As Table 6.4 shows, the delivered cost of bagasse varies from supplier mill to mill, depending on the investments needed to economize on bagasse own-use, the volume of bagasse to be baled and stored, and the cost of transportation to the user. The most efficient use will be made of bagasse and the most accurate price signals given to potential suppliers if: (a) the consumers of bagasse, such as FUEL, are free to negotiate directly with potential suppliers of bagasse and alternative fuels for the purchase of these inputs on a least-cost basis; and (b) the bagasse power generators receive a price for their power that is independent of their fuel choice and based on the cost of alternative power generation.

Bagasse Payment to Planters

6.24 Currently, sugar cane planters are entitled by law to a payment of Rs 100/ton (US$7.4/ton) for bagasse used for purposes other than sugar production. The objective is to distribute to the planters a share of the proceeds from the use of any by-products of the sugar process. Revenue from the payment scheme is shared between the planters in proportion to the share of the total sugar crop produced from their cane. For example, a sugar estate producing 25,000 tons of sugar from its own cane in a year when the island's sugar crop totalled 500,000 tons would be entitled to a 5% share (25,000/500,000 x 100) of the aggregate bagasse payment collected in that year.

6.25 If there was no payment to planters for bagasse used in power generation, the economic benefits from its increased use would be shared between the suppliers of cane and bagasse (the planters and sugar mills), the power generators, the CEB and its customers (electricity consumers). As there are several potential suppliers of bagasse for power, and it is in direct competition with coal, competition to sell bagasse to the generators should allow the latter to capture part of the producers' surplus, the balance of which would be shared between the millers and planters. In turn, the CEB's position as a monopsony buyer of power should allow it to capture part of the surplus from them. Part would be retained by CEB and part passed on to electricity consumers. Electricity consumers and/or tax payers would benefit indirectly from the portion the CEB retained through its contribution to net revenue.

6.26 A payment to planters for bagasse used in power generation redistributes to them a proportion of the economic benefits from its use. However, it also raises the financial cost of bagasse as a generating fuel by an amount equal to Rs 100/ton less the supplier mill's receipts from the bagasse payment scheme. In the example of a supplier mill that contributed 5% of the sugar crop, the net bagasse payment would add Rs 95/ton (Rs 100 - 5%) to the financial cost of any bagasse it supplied for power generation.

6.27 Estimates of the proportion of the bagasse payment that would be rebated to each potential economic supplier of bagasse to the FUEL power plant, of the net bagasse payment made by each supplier, and of the resulting total financial cost of bagasse, are given in Table 6.8. They are based on the mill's average contributions to the total sugar crop over the 1972-81 period. As the table shows, the Rs 100/ton bagasse payment would add between Rs 92 and Rs 100 per ton to the economic cost of bagasse from these sources.

6.28 The impact of the net bagasse payment to planters on the competitiveness of bagasse vis-a-vis coal for power generation at FUEL is illustrated in Figure 6.1. At an economic cost of coal of Rs 750/ton c.i.f. (Rs 950/ton delivered) 126,700 tons of bagasse are competitive without the bagasse payment. With the bagasse payment, 44,500 tons of potential bagasse supplies from Belle Vue (5,500 tons), St. Antoine (11,900), FUEL (14,200), and Union St. Aubin (12,900) become uncompetitive. A further 27,000 tons (16,900 tons from Beau Plan and 10,100 tons from SSRR) become marginally competitive. At a c.i.f. cost of coal of Rs 616/ton, which is probably more representative of world coal prices for the next 5-10 years, the bagasse payment makes all potentially economic supplies of bagasse financially uncompetitive, with the possible exception of 18,700 tons from the least-cost supplier, Constance. These results are summarized in Table 6.9.

Table 6.8: IMPACT OF THE PLANTERS' PAYMENT ON THE COST OF BAGASSE TO THE FUEL POWER PLANT

Potential Bagasse Supplier	Potential Bagasse Supply (1)	Contribution to Sugar crop (2)	Net Bagasse Payment (3)	Economic Cost of Bagasse (4)	Total Financial Cost of Bagasse (5) = (3)+(4)
	(tons)	(%)	(Rs)	(Rs/ton)	(Rs/ton)
Constance	18,900	2.9	97.1	165	262
Soc. Suc. Riv. Remp. I	11,300	0	100.0	177	277
Belle Vue I	25,200	1.2	98.8	184	283
Soc. Suc. Riv. Remp. II	10,100	0	100.0	200	300
Beau Plan	16,900	0.9	99.1	207	306
Belle Vue II	5,500	1.2	98.8	243	342
St. Antoine	11,900	1.4	98.6	257	356
FUEL	14,200	8.0	92.0	271	363
Union St. Aubin	12,900	5.4	94.6	292	387

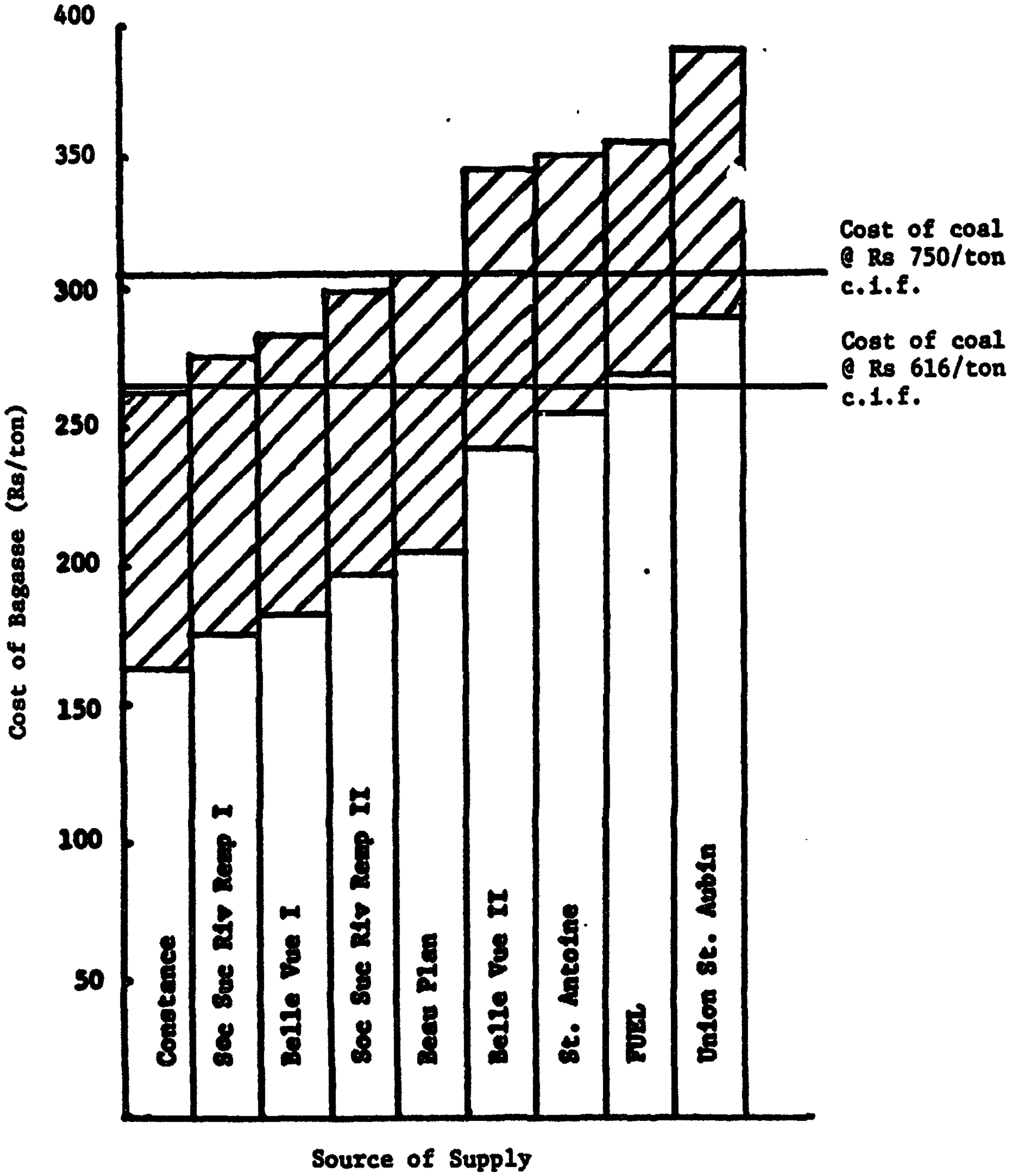
Source: "Mauritius: The Sugar Sector: Problems and Prospects," World Bank report No. 5812-MAS, Table A1.16. Mission estimates.

Table 6.9: IMPACT OF THE RS 100/TON PLANTERS' BAGASSE PAYMENT ON BAGASSE COMPETITIVENESS AT FUEL

Coal @ Rs 750/ton c.i.f.			Coal @ Rs 616/ton c.i.f.		
Impact	Supplier	Quantity	Impact	Supplier	Quantity
		(tons)			(tons)
Uncompetitive	FUEL	14,200	Uncompetitive	U. St. Aubin	12,900
	St. Antoine	11,900		FUEL	14,200
	Belle Vue	5,500		St. Antoine	11,900
	U. St. Aubin	12,900		Belle Vue	30,700
Subtotal		44,500		Beau Plan	16,900
Marginally				S.S.R.R.	21,400
competitive	Beau Plan	16,900	Subtotal		108,000
	S.S.R.R. St.	10,100	Marginally		
Subtotal		27,000	competitive	Constance	18,700
Total potentially affected		71,500	Total potentially affected		126,700

Source: Mission estimates.

Figure 6.1: ECONOMIC AND FINANCIAL COST a/ OF BAGASSE RELATIVE TO COAL AT THE FUEL POWER PLANT



a/ Financial cost equals economic cost plus net bagasse payment to planters.

Legend: ☐ Economic cost of bagasse supply.

▨ Cost of bagasse payment.

Source: Table 6.8.

Economic Implications of Bagasse Payment

6.29 Apart from relatively small quantities that might be competitive as an industrial boiler fuel, bagasse has no alternative use in Mauritius other than in power generation. Its economic opportunity cost is therefore zero. Mauritius will derive maximum economic benefit from the use of its bagasse resources if they are utilized up to a point where the value of the real resources used in supplying the marginal unit of bagasse equals the economic cost of the alternative fuel saved.

6.30 If the bagasse payment to planters, which is a transfer payment and not a real resource cost, has the effect of making economically competitive bagasse supplies financially uncompetitive, it will reduce the quantity of bagasse supplied for power generation and hence the economic benefits from its use. The potential loss to the economy is represented by cost of the substitute fuels which must be imported to replace the lost bagasse.

6.31 At a c.i.f. cost of coal of Rs 750/ton (US$55.6/ton), it is estimated that the current Rs 100/ton bagasse payment to planters would make 44,500 tons of economic bagasse supply to FUEL financially inviable. FUEL would require about 31,800 tons of this least-competitive bagasse to fully replace coal. If, as a result of the bagasse payment, this bagasse supply did not materialize and 10,300 tons of substitute coal imports were required, the annual economic cost to Mauritius would be Rs 7.7 million (US$573,000). If a further 27,000 tons of marginally competitive supply was also lost, the annual economic cost would be Rs 14.3 million (US$1,060,000). At a c.i.f. cost of coal of Rs 616/ton (US$45.6/ton), 95,100 tons of additional bagasse supply would be made uncompetitive by the payment (FUEL's total requirement of 113,800 tons minus 18,700 tons of marginally competitive supply from Constance). This would require 31,000 tons of substitute coal imports, at an annual economic cost to Mauritius of Rs 19.0 million (US$1.4 million).

Recommended Policy

6.32 If the government's objective is to ensure that Mauritius derives maximum economic benefit from use of its bagasse resources, the bagasse payment to planters should not deter any new economic use of bagasse. This means it should be less than the difference between the economic cost of potential marginally competitive bagasse supply and that of its competitor fuel. The only means to ensure this is to exempt from the payment system all bagasse additional to that currently used for power generation. A second-best solution, which carries the risk of deterring some economically-competitive bagasse supply, would be to reduce sharply the level of the payment to a nominal amount per ton.

Economic Returns to Investments in Bagasse Savings and Bulk Handling Facilities for Power Generation

6.33 The viability of investments to maximize the economic use of bagasse for power generation is evaluated by computing their expected net present value (NPV) and economic rate of return (ERR). The investment "project" is defined as the supply of 113,800 tons of baled bagasse for power generation to FUEL from the six least-cost supply sources--Belle Vue, Constance, SSRR, Beau Plan, St. Antoine and FUEL itself.

6.34 The assumed sequence of investments, and the incidence of their associated operating costs, is that hypothesized in paragraph 6.22. In year 1, investment is made in a bagasse baling and storage facility at Constance and in a bale breaking facility at FUEL. A full year's operating cost is assumed for the Constance facility. In year 2, bagasse is transported from Constance to FUEL and a full year's operating cost for baling, storage and breaking incurred at both mills. The amount of 18,700 tons of baled bagasse is delivered from Constance to FUEL, with a coal-substitution value of US$23.3/ton. Benefits are the resulting additional bagasse generation at FUEL, valued on this basis. In year 3, bagasse saving, baling and storage investments are made at Belle Vue, SSRR, Beau Plan and St. Antoine. FUEL also invests in a bagasse dryer to increase its own surplus. A full year's operating costs are incurred, including the loss of revenue from discontinued CEB export "a bien plaire." Benefits consist of bagasse-based generation using supplies from Constance. In year 4, all facilities are assumed to be in operation, the full 113,800 tons of bagasse supplied, and the full benefits of additional bagasse-fired generation realized. A 20-year project life is assumed. Based on the resulting cash flows in Table 6.8, the project is estimated to have a NPV of US$4.8 million at a 14% opportunity cost of capital and an ERR of 36%.

Table 6.10: ESTIMATED COSTS AND BENEFITS OF A BAGASSE POWER PROJECT (US$'000)

Item	Year 1	Year 2	Year 3	Year 4-20
Cost Components				
Investment	919	0	3,327	0
Operating	135	160	517	517
Transport	0	31	31	298
Total Cost	1,054	191	3,875	815
Benefits	0	436	436	2,652
Net Benefits	-1,054	245	-3,439	+1,837

Source: Mission estimates.

Sensitivity Analysis

6.35 Two sensitivity scenarios are hypothesized: (a) a pessimistic scenario, where costs are 10% above base-case estimates and benefits 10% below; and (b) a worst case scenario, where costs are 20% above and benefits 20% below base. The results are set out in Table 6.10. They demonstrate that the project is viable under even the worst case scenario.

Table 6.11: RESULTS OF SENSITIVITY ANALYSIS

Case	NPV (i=14%)	ERR
Base	US$4.8 million	36%
Pessimistic (costs + 10%, benefit -10%)	US$2.9 million	29%
Worst (cost + 20%, benefits - 20%)	US$1.1 million	19%

Source: Mission estimates.

VII. RECOMMENDED FULL-SCALE BAGASSE BALING DEMONSTRATION PROJECT

Rationale and Siting

7.1 Large-bale handling of bagasse, use of which is the key to minimizing its cost and maximizing its use as a generating fuel, is an unfamiliar technology in Mauritius although technically proven elsewhere. Hence, it is recommended that a full-scale large-baling project be implemented to demonstrate the technology to the Mauritian sugar industry. The project would consist of three components: a baling plant, a bale storage facility, and a bale-breaking plant.

7.2 FUEL, the least-cost bagasse generating station, is the most economic site for the bale breaking plant. A sugar mill located nearby, with a substantial surplus of low-cost bagasse, would be the logical site for the bagasse baling and storage facility. Constance, which could produce up to 18,700 tons of surplus bagasse without additional investment and is located only 10 km from FUEL, could be the most suitable location. A project at these locations, is described, costed, and evaluated below. Detailed equipment specifications and a list of recommended vendors are given in Annex 6.

Baling Plant

7.3 Bagasse surplus to Constance's own use requirements would be fed by belt conveyor to a piston-type bale press. The baling process is fully automatic. A hydraulic ram moves forward as soon as the chamber is filled with bagasse. Four wires are tied around each bale by means of an automatic wire-tying device, although manual labor can be used. The wires are supplied from coils located beside the bale press. At the exit of the press, the bales are removed by means of an overhead gantry crane with a gripping device. The bales are then either directly loaded onto a flat bed trailer for transport to the bale storage area or stored in the gantry crane area until the trailer arrives. The maximum capacity of the bale press would need to be 10 tons per hour. Capital cost of the plant would be US$192,582 and operating costs US$59,978 per annum. These are detailed in Table 7.1.

Bale Storage

7.4 The Constance mill has a potential competitive output of 18,700 tons per annum of excess bagasse. To store this amount requires 22 bale stacks of 850 tons each. The space requirement is approximately eight hectares. There should be sufficient distance between the storage area and industrial or domestic areas. It is recommended that a fence be installed around the storage area.

Table 7.1: CONSTANCE BALING PLANT COSTS
(US$)

Item	Local	Foreign	Total
Capital Costs			
Construction			
- site preparation	2,220	-	2,220
- equipment foundations	1,550	600	2,150
- buildings	3,330	2,000	5,330
Sub-total	7,100	2,600	9,700
Equipment			
- feed conveyors and chutes	2,220	4,000	6,220
- material conditioners	--	112,000	112,000
- disch. conveyors and chutes	2,220	4,000	6,220
- handling equipment	8,890	6,000	14,890
Sub-total	13,330	126,000	139,330
Spares at Delivery			
- 7% of value	--	8,820	8,820
Transport and Delivery			
- freight and insurance	--	14,500	14,500
- local charges	2,780	--	2,780
Sub-total	2,780	14,500	17,280
Engineering and Installation			
- engineering cost	1,022	6,430	7,452
- installation	2,500	5,500	8,000
- commissioning	500	1,500	2,000
Sub-total	4,022	13,430	17,452
Total Capital Costs	27,232	165,350	192,582
Operating Costs			
Labor	16,704	--	16,704
Power	1,124	--	1,124
Maintenance	952	1,932	2,884
Insurance	--	536	536
Consumables			
- wire	--	38,230	38,230
-other items	--	500	500
Total cost consumables	--	38,730	38,730
Total Operating Costs	18,780	41,198	59,978

7.5 One tractor and trailer of 20 ton capacity would be sufficient to transport the bagasse to the storage area. A network of compacted driveways around the stacks would allow access for a mobile crane, the tractor and trailer and the Mack trucks, even during bad weather. A ring of water pipes and hose connecting stations would be provided between the stacks for fire fighting. A water reservoir with a pump station would be located near the storage area.

7.6 Bale storage at Constance will require an investment of US$401,690 in capital costs and will cost US$75,384 annually to operate. These expenses are detailed in Table 7.2.

Bale-breaking Plant

7.7 The layout for this facility is shown in Figure 7.1. Trucks arriving at FUEL with bales from Constance (and, eventually, other sugar mills) would be unloaded by means of a gantry crane with a gripping device. The bales from the intermediate store should be transported to the bale breaker by means of tractor and trailers.

7.8 From the trailers, the bales would be placed either directly on to the feed conveyor of the balebreaker (17) or into the intermediate storage area under the gantry crane. The feed conveyor would be equipped with a variable speed drive to regulate the desired feed rate. Both sides along the slat conveyor would be accessible for the removal of baling wires. The wires would be collected and pressed into packages in the wirepress (21) for sale as scrap metal.

7.9 The line of bales would move slowly towards the shredder drum of the bale breaker. The last section of the feed conveyor would be provided with a guide tunnel to prevent the bales from falling apart before reaching the shredder drum. The disintegrated parts would pass through a coarse screen plate at the bottom of the breaker and would then be collected by the conveyor (20). The dust would be exhausted from the breaker casing by means of a dust extraction system (19). This dust is then mixed back into the coarse fraction on the belt conveyor (20) that transports the broken bagasse to the existing bagasse carrier of the boiler feeding system. A magnetic separator (18) on top of the belt conveyor (20) removes wires and other metal that has been overlooked by the operator.

7.10 The bale breaking facility is designed to handle 120,000 tons of bagasse annually, marginally above FUEL's maximum bagasse requirement of 114,000 tons per annum. Such a plant will require US$324,447 in capital and US$25,144 in annual operating costs, as detailed in Table 7.3.

<u>Figure 7.1</u>: LAYOUT OF BALE BREAKING FACILITY AT FUEL

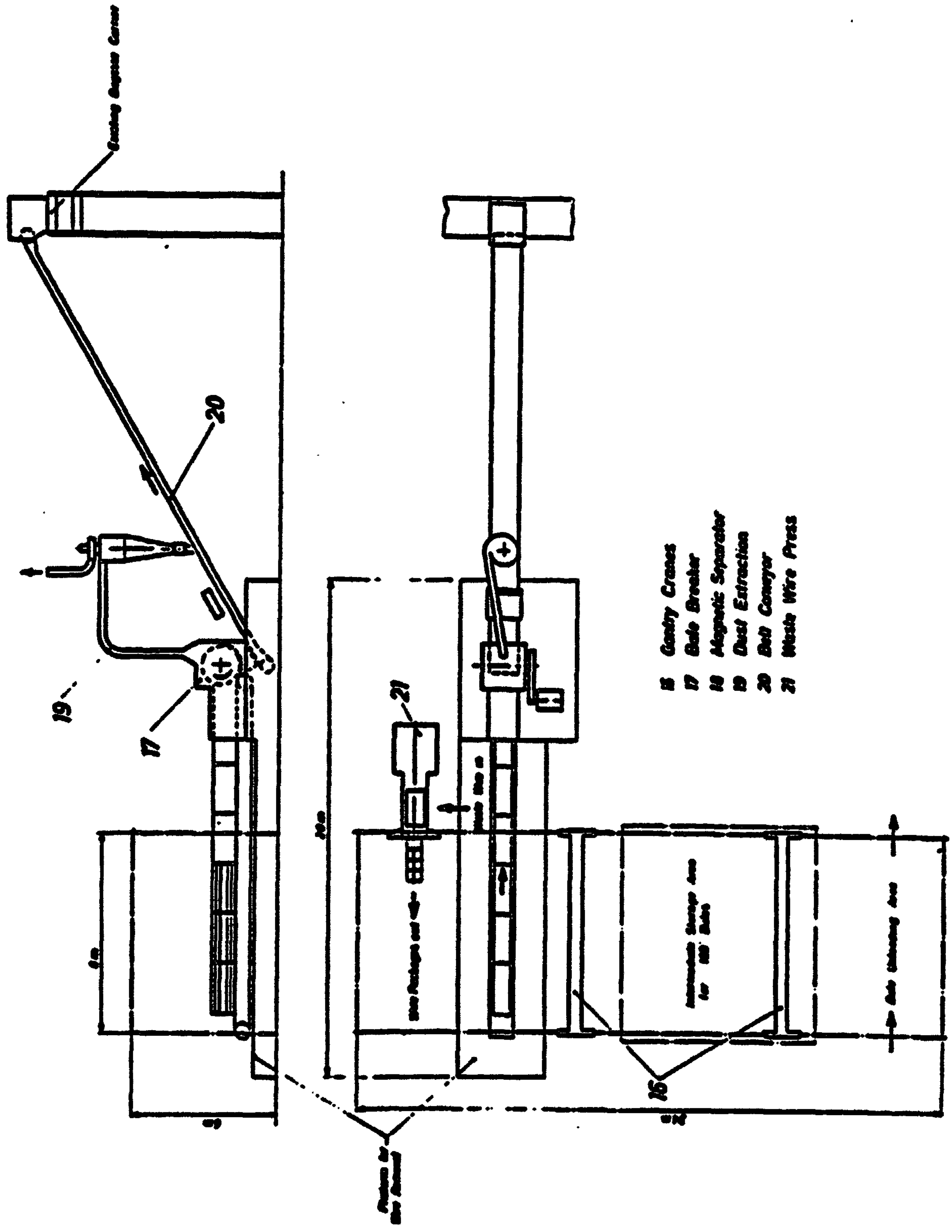


Table 7.2: CONSTANCE BALE STORE COSTS
(US$)

Item	Local	Foreign	Total
Capital Costs			
Construction			
- site preparation	77,800	—	77,800
- buildings	11,000	2,000	13,000
Sub-total	88,800	2,000	90,800
Equipment			
- tractor and trailers		45,000	45,000
- fire fighting	11,000	80,000	91,000
- mobile crane	—	90,000	90,000
Sub-total	11,000	215,000	226,000
Spares at Delivery			
- 7% of value	—	15,050	15,050
Transport and Delivery			
- freight and insurance	—	18,000	18,000
- local charges	4,400	—	4,400
Sub-total	4,400	18,000	22,400
Engineering and Installation			
- engineering	4,990	10,850	15,840
- installation	16,000	15,000	31,000
- commissioning	600	—	600
Sub-total	21,590	25,850	47,440
Total Capital Costs	125,790	275,900	401,690
Operating Costs			
Labor	24,031	—	24,031
Maintenance	4,029	8,179	12,208
Insurance	—	1,245	1,245
Consumables			
-lube oil and grease	—	7,200	7,200
-diesel fuel	—	25,000	25,000
Total Cost Consumables	0	32,200	32,200
Rent	5,700	—	5,700
Total Operating Costs	33,760	41,624	75,384

Table 7.3: FUEL BALE BREAKING FACILITY COSTS

Item	Local	Foreign	Total
Capital Costs			
Construction			
- site preparation	11,000	--	11,000
- buildings	3,330	2,000	5,330
Sub-total	14,330	2,000	16,330
Equipment			
- gantry crane	13,300	12,000	25,300
- bale breaker	6,700	85,000	91,700
- magnetic separator	2,800	23,500	25,300
- dust extraction system	1,700	8,500	10,200
- belt conveyor	2,800	15,500	18,300
- wire press	--	55,000	55,000
Sub-total	27,300	199,500	225,800
Spares at delivery			
- 6% of equipment	--	11,910	11,910
Transport & Delivery			
- freight and insurance	--	17,000	17,000
- local charges	3,300	--	3,300
Sub-total	3,300	17,000	20,300
Engineering and Installation			
- engineering	2,082	10,025	12,107
- installation	25,000	5,000	30,000
- commissioning	3,000	5,000	8,000
Sub-total	30,082	20,025	50,107
Total Capital	75,012	250,435	324,447
Operating Costs			
Labor	2,088	--	2,088
Power	4,531	--	4,531
Maintenance	3,780	7,673	11,453
Insurance		872	872
Consumables			
- lube oil and grease		500	500
Total cost consumables		500	500
Site Costs			
- rent	5,700		5,700
Total Operating Costs	16,099	9,045	25,144

Economic Analysis

7.11 The capital cost of the demonstration project is US$919,000, of which US$228,000 is in local costs and US$691,000 in foreign costs. Annual operating costs are US$160,000, of which US$68,000 is in local costs and US$92,000 in foreign costs. Transporting 18,700 tons of bagasse from Constance to FUEL would cost US$31,000 per annum.

7.12 Benefits consist of additional bagasse-fired power generation at FUEL, substituting for existing coal-fired generation. The coal-equivalent value of bagasse at FUEL is US$23.3/ton. 18,700 tons of bagasse from Constance has an economic value of US$436,000.

7.13 It is assumed that all capital costs and a full year's operating costs for baling and storage are incurred in year one of the project. Operating costs for bale transport and breaking begin in year two, when the full project benefits are realized. The resulting flow of costs and benefits is shown in Table 7.4.

Table 7.4: ESTIMATED COSTS AND BENEFITS OF A BAGASSE BALING DEMONSTRATION PROJECT (US$'000)

Item	Year 1	Year 2-20
Costs		
Capital	919,000	--
Operating		
Baling	60,000	60,000
Storage	75,000	75,000
Transport	--	31,000
Breaking	--	25,000
Total	1,054,000	191,000
Benefits	-	436,000
Net Benefits	-1,054,000	+245,000

Source: Mission estimates.

7.14 Based on this simplified cash flow, the demonstration project has a NPV of US$390,000 at a 14% opportunity cost of capital. Its ERR is 22%. A 10% increase in costs lowers the NPV to US$267,000 and the ERR to 18%.

SUMMARIES OF FACTORY BAGASSE SURPLUS AND INVESTMENT COSTS

Factory : F.U.E.L.

	A	B	C
Cane/yr, tons	700000,00	700000,00	700000,00
TCH	250,00	250,00	250,00
Fibre on cane, %	12,94	12,94	12,94
Bagasse on cane, %	26,96	26,96	26,96
Bagasse/hr, tons	67,40	67,40	67,40
Bagasse available/hr,tons	64,03	64,03	64,03
Process Steam, kg/TC	420,00	406,00	406,00
Process Steam, kg	105000,00	101500,00	101500,00
Bagasse burnt, T/hr	64,03	62,66	58,95
Excess bagasse, T/hr	0,00	1,37	5,08
Excess bagasse, T/yr	0,00	3836,00	14224,00
Investment, US$	0,00	505000,00	950000,00
Operating Cost/yr, US$	0,00	98300,00	188000,00
Cost/ton US$	0,00	25,63	18,10

A = Actual

B = Continuous Vacuum Pan to boil A-Strikes

C = Bagasse Dryer

Factory : MEDINE

	A	B	C
Cane/yr, tons	500000,00	500000,00	500000,00
TCH	175,00	175,00	175,00
Fibre on cane, %	14,04	14,04	14,04
Bagasse on cane, %	29,90	29,90	29,90
Bagasse/hr, tons	52,33	52,33	52,33
Bagasse available/hr,tons	49,71	49,71	49,71
Process Steam, kg/TC	366,00	350,00	350,00
Process Steam, kg	64050,00	61250,00	61250,00
Bagasse burnt, T/hr	49,71	49,15	45,58
Excess bagasse, T/hr	0,00	0,56	4,13
Excess bagasse, T/yr	-3,57	1596,43	11796,43
Investment, US$	0,00	549016,00	890000,00
Operating Cost/yr, US$	0,00	106972,00	177760,00
Cost/ton US$	0,00	66,86	17,43

A = Actual

B = Modifications to evaporator by addition of a 400m2 body
to effect No.2
Addition of a continuous vacuum pan to boil A-Strikes

C = Bagasse Dryer

Factory: CONSTANCE

	A	B	C
Cane/yr, tons	310000,00	310000,00	310000,00
TCH	120,00	120,00	120,00
Fibre on cane, %	14,50	14,50	14,50
Bagasse on cane, %	27,89	27,89	27,89
Bagasse/hr, tons	33,47	33,47	33,47
Bagasse available/hr,tons	31,79	31,79	31,79
Process Steam, kg/TC	492,00	382,00	382,00
Process Steam, kg	59040,00	45840,00	45840,00
Bagasse burnt, T/hr	24,54	20,77	19,65
Excess bagasse, T/hr	7,25	11,02	12,14
Excess bagasse, T/yr	18741,05	28480,22	31373,55
Investment, US$	0,00	1216215,00	890000,00
Operating Cost/yr, US$	0,00	256656,00	177760,00
Cost/ton US$	0,00	26,35	61,44

A = Actual

B = Discontinuing 600kw CEB Export
New 1500 kw condensing turbo alternator
Modifications to Evaporator & juice heaters as follows:-
- New 1600 m2 evaporator body to operate as 1st effect of a quintuple effect
- New 240 m2 juice heater for primary heating of juice from 4th effect vapour
- New 350 m2 juice heater for final heating of juice with 1st effect vapour

C = Bagasse Dryer

Factory: BEAU PLAN

	A	B	C
Cane/yr, tons	300000,00	300000,00	300000,00
TCH	115,00	115,00	115,00
Fibre on cane, %	15,52	15,52	15,52
Bagasse on cane, %	31,50	31,50	31,50
Bagasse/hr, tons	36,23	36,23	36,23
Bagasse available/hr,tons	34,41	34,41	34,41
Process Steam, kg/TC	423,00	392,00	392,00
Process Steam, kg	48645,00	45080,00	45080,00
Bagasse burnt, T/hr	27,95	25,67	24,05
Excess bagasse, T/hr	6,46	8,74	10,36
Excess bagasse, T/yr	16861,96	22809,78	27035,87
Investment, US$	0,00	1600665,00	890000,00
Operating Cost/yr, US$	0,00	206875,00	177760,00
Cost/ton US$	0,00	34,78	42,06

A = Actual

B = - Converting quadruple effect to quintuple effect evaporator by adding new 1535 M2 H.S. 1st vessel

- 225 M2 HS Juice Heater, 290 M2 HS Juice Heater and 160 M2 HS Juice heater to make better use of evaporator vapours

- Continuous vacuum pan for A-Strikes

C = Bagasse Dryer

Factory : BELLE VUE

	A	B	C
Cane/yr, tons	450000,00	450000,00	450000,00
TCH	180,00	180,00	180,00
Fibre on cane, %	15,19	15,19	15,19
Bagasse on cane, %	31,20	31,20	31,20
Bagasse/hr, tons	56,16	56,16	56,16
Bagasse available/hr,tons	53,35	53,35	53,35
Process Steam, kg/TC	472,00	417,00	417,00
Process Steam, kg	84960,00	75060,00	75060,00
Bagasse burnt, T/hr	43,29	41,08	38,15
Excess bagasse, T/hr	10,06	12,27	15,20
Excess bagasse, T/yr	25155,00	30680,00	38005,00
Investment, US$	0,00	100954,00	890000,00
Operating Cost/yr, US$	0,00	24036,00	177760,00
Cost/ton US$	0,00	4,35	24,27

A = Actual

B = 900 kw multistage turbine to drive 1st and 2nd mills

One 35 m2 juice heater

Reducing CEB export power by 138 kw

C = Bagasse Dryer

Factory: MON DESERT ALMA

	A	B	C
Cane/yr, tons	360000,00	360000,00	360000,00
TCH	160,00	160,00	160,00
Fibre on cane, %	13,00	13,00	13,00
Bagasse on cane, %	27,30	27,30	27,30
Bagasse/hr, tons	43,68	43,68	43,68
Bagasse available/hr,tons	41,50	41,50	41,50
Process Steam, kg/TC	492,00	384,00	384,00
Process Steam, kg	78720,00	61440,00	61440,00
Bagasse burnt, T/hr	41,50	32,95	30,52
Excess bagasse, T/hr	0,00	8,55	10,98
Excess bagasse, T/yr	-9,00	19228,50	24696,00
Investment, US$	0,00	378782,00	890000,00
Operating Cost/yr, US$	0,00	109039,00	177760,00
Cost/ton US$	0,00	5,67	32,51

A = Actual

B = Modifications to evaporator and juice heaters as follows:-

- Converting the evaporator to a quintuple effect by adding one 600 M2 body and one 900 M2 body
- New 135 M2 juice heater
- Discontinue 1400 Kw CEB Export

C = Bagasse Dryer

Factory: MON-TRESOR/MON-DESERT

	A	B	C
Cane/yr, tons	280000,00	280000,00	280000,00
TCH	114,00	114,00	114,00
Fibre on cane, %	13,89	13,89	13,89
Bagasse on cane, %	29,00	29,00	29,00
Bagasse/hr, tons	33,06	33,06	33,06
Bagasse available/hr,tons	31,41	31,41	31,41
Process Steam, kg/TC	453,00	412,00	412,00
Process Steam, kg	51642,00	46968,00	46968,00
Bagasse burnt, T/hr	28,76	27,33	24,84
Excess bagasse, T/hr	2,65	4,08	6,57
Excess bagasse, T/yr	6501,40	10013,68	16129,47
Investment, US$	0,00	45801,00	890000,00
Operating Cost/yr, US$	0,00	8924,00	177760,00
Cost/ton US$	0,00	2,54	29,07

A = Actual

B = Addition of a 150 m2 juice heater

C = Bagasse Dryer

Factory: SOCIETE SUCRIERE DE RIVIERE DU REMPART

	A	B	C
Cane/yr, tons	310000,00	310000,00	310000,00
TCH	130,00	130,00	130,00
Fibre on cane, %	14,65	14,65	14,65
Bagasse on cane, %	29,88	29,88	29,88
Bagasse/hr, tons	38,84	38,84	38,84
Bagasse available/hr,tons	36,90	36,90	36,90
Process Steam, kg/TC	380,00	380,00	380,00
Process Steam, kg	49400,00	49400,00	49400,00
Bagasse burnt, T/hr	32,13	27,88	25,81
Excess bagasse, T/hr	4,77	9,02	11,09
Excess bagasse, T/yr	11378,91	21513,52	26449,68
Investment, US$	0,00	100954,00	890000,00
Operating Cost/yr, US$	0,00	17487,00	177760,00
Cost/ton US$	0,00	1,73	36,01

A = Actual

B = Discontinuing 600 kw CEB Export

C = Bagasse Dryer

Factory: RICHE EN EAU

	A	B	C
Cane/yr, tons	275000,00	275000,00	275000,00
TCH	125,00	125,00	125,00
Fibre on cane, %	13,20	13,20	13,20
Bagasse on cane, %	27,31	27,31	27,31
Bagasse/hr, tons	34,14	34,14	34,14
Bagasse available/hr,tons	32,43	32,43	32,43
Process Steam, kg/TC	428,00	369,00	369,00
Process Steam, kg	53500,00	46125,00	46125,00
Bagasse burnt, T/hr	32,40	21,79	21,38
Excess bagasse, T/hr	0,03	7,64	11,05
Excess bagasse, T/yr	67,38	16809,38	24311,38
Investment, US$	0,00	865781,00	890000,00
Operating Cost/yr, US$	0,00	181356,00	177760,00
Cost/ton US$	0,00	10,83	23,70

A = Actual

B = - Converting quadruple effect to quintuple effect evaporator by adding new 1500 M2 HS 1st effect

- 175 M2 HS Juice heater for 2nd stage beating with 3rd vapour
- 110 M2 HS Juice heater for 3rd stage heating with 2nd vapour
- 225 M2 HS Juice heater for final juice heating with steam
- Reduce CEB Export by 440 Kw
- Replace ID fan steam engine drive by electric motor
- 1000 Kw condensing turbo alternator

C = Bagasse Dryer

Factory : MOUNT

	A	B	C
Cane/yr, tons	235000,00	235000,00	235000,00
TCH	100,00	100,00	100,00
Fibre on cane, %	15,04	15,04	15,04
Bagasse on cane, %	30,02	30,02	30,02
Bagasse/hr, tons	30,02	30,02	30,02
Bagasse available/hr,tons	28,52	28,52	28,52
Process Steam, kg/TC	458,00	392,00	392,00
Process Steam, kg	45800,00	39200,00	39200,00
Bagasse burnt, T/hr	28,51	21,39	18,30
Excess bagasse, T/hr	0,01	7,13	10,22
Excess bagasse, T/yr	21,15	16753,15	24014,65
Investment, US$	0,00	3178586,00	890000,00
Operating Cost/yr, US$	0,00	626303,00	177760,00
Cost/ton US$	0,00	37,43	24,48

A = Actual

B = - 1300 m2 HS 1st vessel evaporator to convert existing quadruple effect to quintuple effect evaporator

- 100 m2 juice heater

- New 50T/hr 22 bar water tube boiler to replace existing fire tube boilers

C = Bagasse Dryer

Factory: SAVANNAH

	A	B	C
Cane/yr, tons	310000,00	310000,00	310000,00
TCH	125,90	125,90	125,90
Fibre on cane, %	13,34	13,34	13,34
Bagasse on cane, %	27,05	27,05	27,05
Bagasse/hr, tons	34,06	34,06	34,06
Bagasse available/hr,tons	32,35	32,35	32,35
Process Steam, kg/TC	469,00	399,00	399,00
Process Steam, kg	59047,10	50234,10	50234,10
Bagasse burnt, T/hr	32,13	22,65	18,63
Excess bagasse, T/hr	0,22	9,70	13,72
Excess bagasse, T/yr	549,46	23891,80	33790,13
Investment, US$	0,00	715065,00	890000,00
Operating Cost/yr, US$	0,00	163949,00	177760,00
Cost/ton US$	0,00	7,02	17,96

A = Actual

B = - Conversion of quadruple effect to quintuple effect evaporator by installing a new 900 m2 HS 2nd body

- 220 m2 HS juice heater for 2nd stage juice heating with 3rd vapour from QE

- 160 m2 HS clarified juice heater

- Discontinue 800 kw CEB Export

- 1000 kw condensing turbo alternator

- Replacement of ID fan steam driven by electric motor

C = Bagasse Dryer

Factory: HIGHLANDS

	A	B	C
Cane/yr, tons	275000,00	275000,00	275000,00
TCH	96,70	96,70	96,70
Fibre on cane, %	11,98	11,98	11,98
Bagasse on cane, %	25,33	25,33	25,33
Bagasse/hr, tons	24,49	24,49	24,49
Bagasse available/hr, tons	23,27	23,27	23,27
Process Steam, kg/TC	503,00	396,00	396,00
Process Steam, kg	48640,10	38293,20	38293,20
Bagasse burnt, T/hr	23,01	20,20	16,72
Excess bagasse, T/hr	0,26	3,07	6,55
Excess bagasse, T/yr	737,71	8728,92	18625,50
Investment, US$	0,00	759784,00	890000,00
Operating Cost/yr, US$	0,00	149336,00	177760,00
Cost/ton US$	0,00	18,69	17,96

A = Actual

B = - Converting quadruple effect to quintuple effect evaporator by adding a new 1200 m2 HS

- 200 m2 HS juice heater for 1st stage heating of juice with 4th vapour

- 125 m2 HS juice heater to be placed in series with existing 139 m2 HS heater for 4th stage juice heating with 1st vapour

- Replacement of cane cutters steam engine drives by electric motors

- 1000 kw condensing turbo alternator

C = Bagasse Dryer

Factory : ST ANTOINE

	A	B	C
Cane/yr, tons	250000,00	250000,00	250000,00
TCH	106,10	106,10	106,10
Fibre on cane, %	15,60	15,60	15,60
Bagasse on cane, %	33,60	33,60	33,60
Bagasse/hr, tons	35,65	35,65	35,65
Bagasse available/hr,tons	33,87	33,87	33,87
Process Steam, kg/TC	539,00	461,00	461,00
Process Steam, kg	57187,90	48912,10	48912,10
Bagasse burnt, T/hr	28,81	24,20	19,79
Excess bagasse, T/hr	5,06	9,67	14,08
Excess bagasse, T/yr	11915,93	22778,32	33169,46
Investment, US$	0,00	568433,00	890000,00
Operating Cost/yr, US$	0,00	122615,00	177760,00
Cost/ton US$	0,00	11,29	17,11

A = Actual

B = - Converting existing quadruple effect to quintuple effect by coupling existing 1st and 2nd effects, adding a new 700m2 HS 2nd effect and adding a new 600 m2 HS 3rd effect

- 165 m2 HS juice heater for 4th stage heating with 1st vapour
- Decrease CEB export from 500 to 100 kw
- Replace 1st mill steam engine by 400 kw multistage steam turbine with reduction gears

C = Bagasse Dryer

NOTE : Deduct 8000T/yr for bagasse supply to Particle Board Factory

Factory : BRITANNIA

	A	B	C
Cane/yr, tons	225000,00	225000,00	225000,00
TCH	95,20	95,20	95,20
Fibre on cane, %	12,37	12,37	12,37
Bagasse on cane, %	25,21	25,21	25,21
Bagasse/hr, tons	24,00	24,00	24,00
Bagasse available/hr,tons	22,80	22,80	22,80
Process Steam, kg/TC	488,00	398,00	398,00
Process Steam, kg	46457,60	37889,60	37889,60
Bagasse burnt, T/hr	22,80	19,61	16,15
Excess bagasse, T/hr	0,00	3,19	6,65
Excess bagasse, T/yr	-0,18	7539,21	15712,01
Investment, US$	0,00	444740,00	890000,00
Operating Cost/yr, US$	0,00	87193,00	177760,00
Cost/ton US$	0,00	11,56	21,75

A = Actual

B = - Converting existing quadruple effect to quintuple effect by adding new 1400 m2 HS 1st effect, coupling existing effects Nos.2 and 3 and adding a new 400 m2 HS 5th effect

- 125 m2 HS juice heater for 2nd stage heating with 3rd vapour

- Replacing various stem drives, pumps etc. by electric motors

C = Bagasse Dryer

NOTE : With the installation of a new HP boiler, already purchased, the mill drives will have a better water rate as they are designed to operate at 26 bar

Factory - Union St Aubin

	A	B	C
Cane/yr, tons	270000,00	270000,00	270000,00
TCH	112,53	112,53	112,53
Fibre on cane, %	13,39	13,39	13,39
Bagasse on cane, %	27,60	27,60	27,60
Bagasse/hr, tons	31,06	31,06	31,06
Bagasse available/hr, tons	29,51	29,51	29,51
Process Steam, kg/TC	413,00	380,00	380,00
Process Steam, kg	46474,89	42761,40	42761,40
Bagasse burnt, T/hr	24,11	22,26	20,65
Excess bagasse, T/hr	5,40	7,25	8,86
Excess bagasse, T/yr	12945,43	17384,24	21247,21
Investment, US$	0,00	152717,00	890000,00
Operating Cost/yr, US$	0,00	29808,00	177760,00
Cost/ton US$	0,00	6,72	46,02

A = Actual

B = Modifications evaporator and juice heaters as follows:-

1st effect : 1046 m2 existing

2nd effect : 1132 m2 required, this can be done by using existing 2nd and 3rd effects in parallel with will give 1162 m2

3rd effect : 581 m2 existing

4th effect : 581 m2 existing 5th effect

5th effect : New 400 m2

One new 225m2 juice heater for primary juice heating with vapour from 4th effect

C = Bagasse Dryer

SUMMARY OF INVESTMENTS AND COSTS

FACTORY	Sc.	EQUIPMENT	LIFE Yrs	INVESTMENTS US $ Foreign	Local	Total	OPERATING COSTS US $/yr. Foreign	Local	Total
F.U.E.L.	B	Continuous Vacuum Pan	25	187000	318000	505000	75880	22420	98300
	C	Dryer	25	580000	370000	950000	140672	47328	188000
MEDINE	B	Continuous Vacuum Pan	25	170000	295000	465000	69900	20650	90550
		400 M2 H.S. Evaporator	25	31656	52360	84016	12726	3696	16422
	C	Dryer	25	544000	346000	890000	133010	44750	177760
CONSTANCE	B	240 M2 H.S. Juice Heater	25	26952	46330	73282	11070	3208	14278
		360 M2 H.S. Juice Heater	25	39305	67564	106869	16145	4679	20824
		1600 M2 H.S. Evaporator	25	126624	209440	336064	50904	14782	65686
		1500 Kw Condensing T/A	25	654000	46000	700000	106500	31000	137500
		CEB Export loss, 600 kw						18368	18368
	C	Dryer	25	544000	346000	890000	133010	44750	177760
BEAU PLAN	B	160 M2 H.S. Juice Heater	25	17968	30886	48854	7381	2139	9520
		290 M2 H.S. Juice Heater	25	32567	55981	88548	13376	3877	17253
		225 M2 H.S. Juice Heater	25	25267	43434	68701	10378	3008	13386
		1550 M2 H.S. Evaporator	25	122667	202895	325562	49312	14320	63632
		Continuous Vacuum Pan	25	165000	285000	450000	67645	19980	87625
		CEB Export Loss, 600 kw						15459	15459
	C	Dryer	25	544000	346000	890000	133010	44750	177760
BELLE VUE	B	85 M2 H.S. Juice Heater	25	9546	16408	25954	3921	1136	5057
		900kw ms.st.turbine 1st mill	25	71000	4000	75000	11510	3380	14890
		CEB Export loss, 138 kw						4089	4089
	C	Dryer	25	544000	346000	890000	133010	44750	177760
M.D.ALMA	B	135 M2 H.S. Juiçe Heater	25	15160	26060	41220	6228	1805	8033
		600 M2 H.S. Evaporator	25	47484	78540	126024	19089	5543	24632
		950 M2 H.S. Evaporator	25	75183	124355	199538	30224	8777	39001
		Relocation of effect No.4			12000	12000			
		CEB Export loss, 1400 kw						37373	37373
	C	Dryer	25	544000	346000	890000	133010	44750	177760
M.T./M.DESERT	B	150 M2 H.S. Juice Heater	25	16845	28956	45801	6919	2005	8924
	C	Dryer	25	544000	346000	890000	133010	44750	177760
Ste.S.R.R.	B	CEB Export loss,600Kw	25					16953	16953
	C	Dryer	25	544000	346000	890000	133010	44750	177760

R.E.Eau	B	175 M2 H.S. Juice Heater	25	19653	33782	53435	8073	2340	10413
		225 M2 H.S. Juice Heater	25	25267	43434	68701	10378	3008	13386
		110 M2 H.S. Juice Heater	25	12353	21234	33587	5074	1470	6544
		1500 M2 H.S. Evaporator	25	118710	196350	315060	47723	13858	61581
		1000 Kw Cond.Turbo Altern.	25	355000	25000	380000	57925	16950	74875
		Electric Motors	20	12630	2368	14998	2270	813	3083
		CEB Export loss, 440 kw						11472	11472
	C	Dryer	25	544000	346000	890000	133010	44750	177760
MOUNT	B	100 M2 H.S. Juice Heater	25	11230	19304	30534	4613	1337	5950
		1300 M2 H.S. Evaporator	25	102882	170170	273052	41360	12011	53371
		Electric motors	20	21050	3950	25000	3784	1355	5139
		50 T/hr H.P. Boiler	25	2700000	150000	2850000	434843	127000	561843
	C	Dryer	25	544000	346000	890000	133010	44750	177760
SAVANNAH	B	160 M2 H.S. Juice Heater	25	17968	30886	48854	7381	2139	9520
		220 M2 H.S. Juice Heater	25	24706	42469	67175	10148	2941	13089
		900 M2 H.S. Evaporator	25	71226	117810	189036	28633	8315	36948
		1000 kw Cond.Turbo Altern.	25	355000	25000	380000	57925	16950	74875
		Electric Motors	20	25260	4740	30000	4540	1626	6166
		CEB Export loss, 800 kw						23351	23351
	C	Dryer	25	544000	346000	890000	133010	44750	177760
HIGHLANDS	B	125 M2 H.S. Juice Heater	25	14037	24131	38168	5765	1671	7436
		200 M2 H.S. Juice Heater	25	22460	38608	61068	9226	2674	11900
		1200 M2 H.S. Evaporator	25	94968	157080	252048	38178	11087	49265
		1000 Kw Cond. Turbo Altern.	25	355000	25000	380000	57925	16950	74875
		El.Drives for C.C.1 & 2	20	24000	4500	28500	4314	1545	5859
	C	Dryer	25	544000	346000	890000	133010	44750	177760
ST.ANTOINE	B	165 M2 H.S. Juice Heater	25	18530	31852	50382	7611	2206	9817
		700 M2 H.S. Evaporator	25	55398	91630	147028	22271	6467	28738
		600 M2 H.S. Evaporator	25	47484	78540	126024	19089	5543	24632
		400 kw 1st mill Drive	25	230000	15000	245000	37358	10900	48258
		CEB Export loss, 400 kw						11170	11170
	C	Dryer	25	544000	346000	890000	133010	44750	177760
BRITANNIA	B	125 M2 H.S. Juice Heater	25	14037	24130	38167	5765	1671	7436
		1400 M2 H.S. Evaporator	25	110796	183260	294056	44541	12934	57475
		400 M2 H.S. Evaporator	25	31656	52360	84016	12726	3696	16422
		Electric motors	20	24000	4500	28500	4314	1545	5859
	C	Dryer	25	544000	346000	890000	133010	44750	177760
U.S.AUBIN	B	225 M2 H.S. Juice Heater	25	25267	43434	68701	10378	3008	13386
		400 M2 H.S. Evaporator	25	31656	52360	84016	12726	3696	16422
	C	Dryer	25	544000	346000	890000	133010	44750	17760

Notes :- 1 - Interest on capital 14%

2 - Excess bagasse is cumulative, cost/ton is on increment from B to C

3 - P = Paying, NP = Non-Paying before complete investment is effected.

DESCRIPTION AND COST OF ALTERNATIVE BAGASSE HANDLING SYSTEMS

Introduction

1. Detailed descriptions of three handling systems--pelletizing, briquetting and baling--and their comparative cost are presented below. The loose piling option has not been assessed due to the significant problems described above which preclude it from further consideration. For the design of each process, the capacities of bagasse processing equipment were sized to handle potential peak throughput, i.e., when cane with the highest fiber content is crushed. The capacities of the storage areas were designed to accommodate the peak quantities of excess bagasse.

Bagasse Pellets

Process Description

2. A bagasse pelletization system for 15 of the larger sugar mills in Mauritius would consist of twelve pelleting plants (dryer + pelletizer) at the mills which do not generate power and three pre-dryers at the generating mills. A two-stage drying system will be used to bring the bagasse down to 35% m.c. for boiler efficiency and then down to the 10-12% moisture content required for pelletizing. For storage, twelve pellet stores capable of holding 210,000 tons (10% m.c.) for the intercrop season would be needed. Pellets would be stored in bulk in tent-shaped buildings. A net storage volume of 350,000 m^3/year would be required. In-store distribution is done with overhead conveyor systems and trucks can be filled with payloaders. This system is more economic than silos for the quantities that must be stored. Transport to the three mill power plants would be done during the intercrop season with existing Mack-type sugar trucks. With a bulk density of 600 kg/cubic meter, 24 tons of pellets could be hauled by each truck per trip. For a theoretical maximum of 210,000 tons per annum, 8,750 trips would be required with each trip averaging 20.5 km one way. Once the pellets were delivered, they would be burned in the boilers at each power plant to produce electricity. Only the new Fives-Cail-Babcock boiler at FUEL is currently designed to burn pellets. The boilers at Medine and Mon Tresor would require some modification if they are to consume pellets. Modification costs have not been estimated below but should not significantly affect the final price of the product.

Financial Costs

3. Some of the figures used in this calculation were obtained from the Bagapel pelletizing plant at the Beau Champ sugar mill. However, it was not possible to obtain actual operating costs since, to date, the plant has not operated continuously over a sufficiently representative period of time; thus, these costs have been based on experience with similar equipment elsewhere.

4. The combined capital and operating costs for twelve pelleting plants and three pre-dryers are presented below in Table 1.

Table 1: CAPITAL AND OPERATING COSTS FOR PELLETIZATION

Item	Cost	
	(US$'000)	(US$/ton, 10% m.c.)
I. Pelleting and Drying Equipment		
A. Capital	35,500	21.90
B. Operating		
- Labor	312	1.49
- Power (22 GWh)	330	1.57
- Maintenance	1,250	5.95
Subtotal	1,892	9.01
II. Storage		
A. Capital	9,000	5.14
B. Operating	350	1.67
III. Transport	715	3.40
Subtotal, capital	44,500	27.04
Subtotal, operating	2,957	14.08
Total		41.12

a/ 10% discount rate for annualization.

Source: Mission estimates

Thus, pellets would cost $41.12/ton to produce and transport. In energy terms, this is equivalent to $2.64/GJ. The actual figure would be slightly higher as costs for boiler modifications have not been incorporated.

Bagasse Briquettes

Process Description

5. Each of the 15 mills would be equipped with a pre-dryer that is operated with boiler flue gases to dry all the bagasse to approximately 35% m.c. before feeding the sugar mill boilers. The excess would pass through secondary dryers to reach a final moisture content of 10-12%. The heat for these dryers will be provided by bagasse-fired incinerators. Thus, the dependence on a steady flue gas supply from the sugar mill boilers can be eliminated. This dependence is one of the operating problems at the Bagapel plant. The fines that contain dust, soot and abrasives will be screened out before the final drying stage. This will reduce wear on the briquetting press substantially. The dry bagasse will then be densified into briquettes of 90 mm diameter by means of twin-head piston briquettors. The hourly briquetting capacity required for the maximum potential excess bagasse is about 80 tons per hour; thus, 40 briquettors are required. The smallest mill would be equipped with three briquettors and the largest with eight machines. For storage, the same methods used with pellets is recommended. As the existing power plant boilers are not suited to burning large-diameter briquettes, the briquettes will be crushed before being fed to the boilers. The costs for three crushing machines located at the power plants are included in the cost calculation.

Financial Costs

6. Fifteen pre-drying plants will be required for this system the capital and operating costs of which are summarized in Table 2. For the off-season, 210,000 tons of 10% m.c. briquettes will have to be stored, requiring a net storage volume of 420,000 m^3 or a gross storage building volume of 650,000 m^3. For transport, Mack-type sugar trucks will also be used but with slightly larger containers than the current ones (12 instead of 10 m3). Bagasse briquettes would cost $31.46 per ton to produce and transport to the power plant boilers. In energy terms, this is equivalent to $2.06/GJ.

Table 2: BAGASSE BRIQUETTING COSTS

Item	Cost (US$'000)	Cost (US$/ton, 10% m.c.)
I. Pre-drying plants		
A. Capital	4,720	2.96
B. Operating	234	1.11
II. Briquetting plants		
A. Capital	13,500	8.28
B. Operating	1,220	5.81
III. Storage		
A. Capital	11,000	6.15
B. Operating	390	1.85
IV. Transport	715	3.40
V. Crushing		
A. Capital	1,200	0.74
B. Operating		
- labor	60	0.29
- power (3.1 GWh)	109	0.52
- maintenance	74	0.35
Sub-total	243	1.16
Subtotal, capital	30,420	18.13
Subtotal, operating	2,801	13.33
Total		31.46

a/ 10% discount rate for annualization.

Source: Mission estimates

Baled Bagasse

Process Description

7. Bale presses. The surplus bagasse that is not consumed by the sugar mill boilers would be conveyed to a bale press. These are hydraulic presses that produce large bales (1.5 m^3 weighing 600 kg each). The tying of the binding wires is done automatically. Each press has a capacity of 17-20 tons per hour of bagasse. Two mills would be equipped with two bale presses and the other eleven mills with one press each. For the cost calculations, no bale presses have been included for the three mills with condensing turbo-alternators since all their excess bagasse would be used for power production during the crop season. For operational security reasons, it may be necessary to install a press at each of these mills in the boiler is not able to burn surplus bagasse immediately due to a shutdown.

8. Bale storage. Bales would be transported to an open-air storage area by a tractor-trailer. The bales are loaded onto the trailer with a small gantry-type hoist near the bale press. At the bale store, the unloading and stacking is done by means of a mobile crane. Sufficient spaces would be provided between the bale stacks to allow isolation of a single stack in the event of fire. Fire-fighting equipment would consist of a pipe network with hose reels between the stacks. A separate water reservoir with a pump station would be provided for the fire suppression water supply. The spaces between the stacks would be kept clear of loose bagasse and weeds.

9. Transport. Transport to mill power plants would take place during the intercrop season by means of idle sugar trucks. A Mack-truck with two trailers, each with a loading platform of 2.4 m x 6.2 m, can load 52 bales (490 kg each with 20% m.c. after storage). Thus, 25 tons could be transported with each truckload. These trucks are currently operating in Mauritius. At the point of consumption, the bales would be unloaded by a small gantry-type hoist adjacent to the balebreaking plant.

10. Balebreaking. At each of the three electricity-generating mills a balebreaker would be installed. The bales would be fed onto the feeding conveyor of the balebreaker by means of the same hoist that is used to unload the trucks. One worker would remove the binding wires when the bales are on the feeding conveyor. The waste wires would then be pressed into bundles by means of a hydraulic press; these could then be sold as scrap metal. The bales themselves would be broken by means of a toothed rotor. Then, the loose bagasse would be collected on a belt conveyor that is equipped with a strong electromagnetic separator. The conveyor feeds the bagasse into the feeding system of the boiler. To avoid excessive dust formation, the balebreaker would have a dust exhaust system.

Financial Costs

11. Twelve automatic baling plants will make bales of the 35% m.c. bagasse; each bale will have an initial weight of 600 kg and a volume of 1.5 m^3. Open-air bale stores will require 4 m^2 of land per ton of bagasse; the initial moisture content will reduce to 20% after storage for several months. For transport, the costs of loading and unloading are included in the calculations for the bale stores and balebreaking plants. Transport cost calculations are detailed in Annex 4. Assuming an average of two round-trips per shift and 230 days for the intercrop season, 7-8 trucks would be required for the distribution of the bales to the power plants. Currently, there are thirteen of these Mac trucks lying idle during the off-season.

12. A detailed breakdown of local, foreign and total costs for each phase of the baling system is provided in Table 3. Bagasse baling and transport to the power plants costs about $13.91/ton. In energy terms, this is equivalent to a cost of $1.05/GJ.

Table 3: BALED BAGASSE CAPITAL AND OPERATING COSTS
(US$)

Item	Local	Foreign	Total	$/Ton a/
I. Baling plants				
A. Capital				
- construction	150	30	180.00	
- equipment	50	1,785	1,835.00	
- spares at del.	0	93	93.00	
- transport	30	155	185.00	
- eng. & install	40	250	290.00	
Subtotal	270	2,313	2,583.00	1.30
B. Operating				
- labor	168	0	168.00	
- power (1.3 GWh)	19	0	19.00	
- maintenance	25	60	85.00	
- binding wire	0	384	384.00	
Subtotal	212	444	656.00	2.52
II. Bale stores				
A. Capital				
- construction	1,080	144	1,224.00	
- equipment	60	3,360	3,420.00	
- spares at del.	0	72	72.00	
- transport	24	156	180.00	
- eng. & install	48	156	204.00	
Subtotal	1,212	3,888	5,100.00	2.50
B. Operating				
- labor	360	0	360.00	
- power (diesel)	0	80	80.00	
- maintenance	130	200	330.00	
- land rent	53	0	53.00	
Subtotal	543	280	823.00	3.16
III. Transport	0	886	886.00	3.41
IV. Bale breaking				
A. Capital				
- construction	33	3	36.00	
- equipment	85	535	620.00	
- spares at del.	0	30	30.00	
- transport	8	62	70.00	
- eng. & install	25	80	105.00	
Subtotal	151	710	861.00	0.43
B. Operating				
- labor	72	0	72.00	
- power (1.6 GWh)	57	0	57.00	
- maintenance	10	15	25.00	
Subtotal	139	15	154.00	0.59
Subtotal, capital			3,933.00	4.23
Subtotal, operating			2,519.57	9.68
Total				13.91

a/ 10% discount rate for annualization.

Source:

FINANCIAL ASSUMPTIONS

Basic data used for cost calculations

-- exchange rates	:	Rs 15/$, FF 8.5/$ SFr 2.2/$, DM 2.7/$
-- discount rate	:	10%
-- electricity ($/kWh)	:	during crop season 0.015
	:	during intercrop season, 0.035
-- diesel	:	0.3 $/liter (0.85 kg/liter)
-- transport	:	0.17 $/ton-km (based on 24 tons/trip
-- binding wire	:	0.6 $/kg
-- site costs (rent)	:	415 $/hectare, year (5% p.a. from Rs 50,000 per acre)

Plant life

-- construction, building	:	20 years
-- equipment, spares, etc.	:	15 years

Labor	$/year	4 shifts*
-- unskilled	1,500	6,000
-- semiskilled	2,000	8,000
-- skilled	2,500	10,000

* All labor costs are based on 4 shift operations.

Basic data for energy calculations

NCV of bagasse calculated with MSIRI formula:

@ 50% m.c.	:	7,380
@ 45% m.c.	:	8,370
@ 35% m.c.	:	10,350
@ 20% m.c.	:	13,320
@ 10% m.c.	:	15,300

NCV of coal : 27,000 kJ/kg

TRANSPORT CALCULATIONS

Assumptions

For all three handling options, transport would be by existing Mack-type trucks, which have two trailers, each with a platform 2.4 m wide x 6.2 m long, holding two containers per trailer. The assumed transport charge is \$0.166/ton kilometer (Rs 4/ton mile).

Pellets

With a bulk density of 600 kg per cubic meter, 24 tons of pellets could be loaded on each truck in four containers, each with a volume of 10 m^3. With 210,000 tons of pellets per year, 8750 trips would be required. If transport is operated for three shifts per day, with two round-trips made per shift and the intercrop season an average of 230 days, then seven trucks would be required. Assuming the above distribution of fuel needs per power plant, the average transport distance would be 20.5 km one way. Thus, transport costs would be 20.5 km x 210,000 tons x \$0.166/ton km = \$714,630 or \$3.4/ton.

Briquettes

With larger containers (4 x 12 m^3 instead of 4 x 10 m^3), each truck would carry 24 tons of briquettes. With 210,000 tons per year required, 8750 trips would be taken over an average distance of 20.5 km and seven trucks would be required. Thus, transport costs for briquettes are identical to those for pellets (\$3.4/ton).

Bales

An average of 260,000 tons of bales would have to be transported annually; this amounts to 533,333 bales weighing 488 kg. each (20% m.c.). A Mack truck can load 52 bales or 25 tons per trip (see Figure 3). Transport to FUEL would be: 16 km x 153,400 tons x \$0.166/ton km = \$407,430. Transport to Médine would be: 34 km x 67,600 tons x \$0.166 = \$381,530. Transport to Mon Trésor would be: 15 km x 39,000 tons x \$0.166 = \$97,110. Thus, total transport costs for bales amount to \$886,070 per annum or \$3.41 per ton.

With 260,000 tons per annum and 25 tons per trip, the trucks would have to make 10,400 trips per intercrop season. If transport was carried out in a three-shift operation, and assuming two round-trips per shift with a 230-day intercrop season, 8 trucks would be required for the distribution of bales to power plants.

REVIEW OF THE "BAGATEX 20" BAGASSE BALING SYSTEM AS OPERATED BY THE SANTA LYDIA SUGAR FACTORY, BRAZIL

Process Description

At the beginning of the sugar season, a 10 tonne/hr chain drive shredder (manually fed by forklift) feeds the Bagatex 20 (B20) to an uncovered conveyor which inputs the B20 into the normal boiler bagasse feed system. Once a surplus of bagasse is generated, it is moved by small tractor to a conveyor that feeds into the treatment shed. The conveyor feeds into the bale press which is a piston press similar to a waste paper press. The press capacity is 10 tonnes per hour. As the bagasse drops into the bale press, it is sprayed with a chemical catalyzer. After pressing, the bales are manually tied with wire and moved outside by an overhead lift. Bale size is flexible and ranges from $0.72m^3$ to $1.44m^3$.

The bagasse is then piled manually between 2x2 inch wooden slats (not pallets). A fork lift transfers the piles to a maturing shed that is probably more sturdy and costly than necessary. When the shed is full, outside storage under plastic sheets is used for maturation. This is satisfactory provided the plastic does not touch the tops and sides of the bales, thus permitting unrestricted air circulation. Roughly 2.3-2.7 tons can be stored per m^2 of storage area, and the maturing facility should be sized accordingly.

To handle 40,000 tonnes of bagasse, the Usina Santa Lydia sugar factory employs 22 people on a 3-shift operation (6 people per shift for processing and an extra 4 people on day shift only for inventory control). The only "skilled" personnel employed are the drivers. Other skills are taught during training in operating the process machines.

Financial Evaluation

A conservative estimate of the cost of the B20 process at the Santa Lydia sugar factory (excluding royalty charges) is set out in Table 1.

Performance

B20 does not appear to deteriorate over a 4-year period if rain protected. User experience suggests that boiler operations are not adversely affected by switching to B20. Concerns with combustion temperatures and tube metal temperatures appear to be overstated. Operational changes in fuel/air ratios generally can handle any such variations. There appears to be no "magic" in the process that will inhibit its successful application in Mauritius and other similar environments.

Table 1: Estimated Cost of the Bagatex 20 Process a/

			US$	$/tonne
I.	Capital Costs			
	A.	Site preparation and bldg.	$260,000	.98
	B.	Equipment	258,000	1.09
		- feed chute	6,000	
		- belt conveyor	9,000	
		- bale press (1)	168,000 b/	
		- wood stick separator stock	3,000	
		- fork lifts (3)	60,000	
		- tractors (1)	12,000	
	C.	Spares	18,060	.07
	D.	Transport and Delivery	37,295	.16
	E.	Engineering and Installation	75,500	.32
			Subtotal	$2.62
II.	Operating Costs			
	A.	Labor	26,000	.83
	B.	Power	23,225 c/	.74
	C.	Maintenance	28,640 d/	.92
	D.	Consumables	26,000	.82
			Subtotal	$3.31
			Total	= $5.93

a/ Based on throughput of 40,000 tonnes/year.
b/ Assuming 15 tonne/hour press.
c/ Assuming lube oil recycling, which reduces cost to $8,000/year.
d/ Assuming 50% of cost is attributed to sugar factory as tools and labor are shared.

Annex 5
page 1 of 10

EQUIPMENT SPECIFICATIONS FOR RECOMMENDED BALING PROJECT

I. GENERAL REQUIREMENTS

1.1 All equipment proposed by possible suppliers must be of simple design and easy to operate.

1.2 The proposed equipment must be described in detail with the offer. Construction materials and the type of components must be indicated. Pamphlets and actual or typical drawings must be provided with the offer. If possible, a list of similar reference installations should be provided.

1.3 Special Tools

Any special tools for maintenance and/or for operation of the equipment must be indicated and included with the offer.

1.4 Spare Parts

Basic spare parts for the first 2000 operating hours must be offered as a separate item.

The supplier must guarantee the supply of spare parts for a period of at least 15 years after delivery at competitive prices. Should he not be in a position to supply spare parts any more then he must provide drawings and specifications.

1.5 Painting

All ferrous metal surfaces without machined finishes must either be zinc-bath coated or must be provided with one coat of primer and one coat of finish paint after the surface has been sandblasted or cleaned with a wire brush. Surfaces with machined finishes must be provided with a removeable protective coat to avoid the formation of rust.

All bolts, nuts and washers must be galvanized or promatized.

1.6 Electric Motors

All electric motors should be according to the IEC standard, they must be the squirrel cage type T.E.F.C. (totally enclosed fan cooled). Degree of protection: IP 54 acc. to IEC. Insulation class B acc. to VDE 0530 (German electric standard). They must be suitable for continuous operation (around the clock). All gear motors are to be from SEW. No drum type motors are desired for belt conveyors. Electric power: 380 V, 50 cycles.

1.7 Motor Controls

All motor controls must be offered with the equipment. Motor starters, fuses, push buttons, indicating lamps and relays with spare I/O'S to incorporate some logic interlocks from other plant components must be offered in panels. Starters for motors with more than 10 kW power rating are to be of the star-delta type. Push buttons will generally be installed at sight distance from the equipment. The motor controls of some equipment will be incorporated in the L.V. switchboard. The motor control components will be standardized as much as possible during detailed planning to facilitate the spares requirements.

1.8 Guards

Belt drives and other rotating parts must be protected with guards acc. to DIN 31001 (German general standard). Sight contact with the rotating parts should be allowed as much as possible by using wire mesh surfaces.

1.9 Belt conveyors

Upper belt idlers must be 20° troughed. Diameters of drive and return pulleys must be large. They must be supported in grease-lubricated ball bearing pillow blocks with sealed housings. Drive pulleys must be provided with a snub pulley to obtain additional wrap. The belts must consist of three-ply polyester reinforced material. Cleaning scrapers must be provided in front of the return pulleys to avoid material built-up on the interior surface of the belt. The loading chutes are provided with skirt plates sufficiently long to avoid overspillage of bagasse. The drives must consist of shaft-mounted reduction gears, v-belt drives, belt guards and electric motor mounted on adjustable supporting plates. Access for maintenance and supervision must be granted by a walkway all along one side of the conveyor.

1.10 Manuals

The supplier must provide operating and maintenance manuals, spare part lists and drawings in French and English after receitpt of the order.

II. EQUIPMENT SPECIFICATION FOR PREDRYING 1/ AND BALING EQUIPMENT

2.1 BAGASSE CHUTE WITH SLIDING GATE AND BELT CONVEYORS

Flow sheet item no. 2, 3.1, 3.2

Qty 1 off, each

Intended use: to convey bagasse from the existing mill carrier to the inlet feed screw of the rotary drum dryer. The chute must be provided with a manually operated sliding gate that allows for interrupting and adjusting the flow rate in accordance with the flue gas exhaust temperature of the dryer.

Capacity: up to 38 tons/h of bagasse with 45-50% m.c. Bulk density approx. 80-100 kg/m^3

Construction: The conveyors must be provided with sealed chutes at the charging and discharging ends to avoid formation of dust. The conveyors must be supported from the floor level and a walkway must be provided along on one side of the conveyors.

Overall lengths:

item 3.1: 40m
item 3.2: 23m

The sliding gate must be fitted underneath the existing 1.2 m wide bagasse carrier.

2.2 FLUE GAS DUCT WITH INLET DAMPER

Item no.: 4

Qty: 1

Intended use: to aspirate the flue gases from the existing chimney at the discharge port of the ID fan and to convey the flue gases to the inlet of the rotary drum dryer.

Capacity: up to 180'000 m^3/h with temperatures up to 300°C.

Construction: made of mild steel sheet metal. The connecting piece at

1/ Analysis by the 1986 mission showed that installation of a bagasse drying facility is not economic. A description of this part of the bagasse baling system is retained for the sake of completeness.

the chimney must be provided with an isolating damper to isolate the dryer plant and discharge of the flue gases through the chimney when the dryer is not operating. The duct must be provided with insulation and it must be supported from the floor level. Overall length approx. 35 m.

2.3 ROTARY DRUM DRYER

Item no.: 5

Qty: 1

Intended use: to pre-dry bagasse with boiler flue gases.

Capacity: infeed up to 38 tons/h of bagasse @ 45-50% m.c. with a bulk density of approx. 80-100 kg/m^3. Flue gases: 120'000 -180'000 m^3/h with 220-300°C inlet temperature. Humidity of flue gases at dryer inlet: 115g/kg. Expected humidity at cyclone outlet: 175 g/kg when operated with 250°C at inlet and 95°C at oulet.

Construction: made of structural and sheet metal mild steel with air locks at bagasse inlet and outlet to avoid bleeding of fresh air into dryer; collecting hopper at discharge end to collect the coarse particles of the bagasse and discharge onto a belt conveyor; exhaust fan, ductwork and cyclone separator(s); screw conveyor to collect the dust from the cyclones and discharge onto belt conveyor.

All parts in contact with flue gases must be insulated to avoid condensation. The dryer must be designed to avoid deposits of bagasse and/or dead corners that can cause "cold spots: and condensation. The rotary drum is supported by concrete posts. Collecting hopper, exhaust fan, ductwork, cyclones and dust screw conveyor must all be supplied with supports to the floor level. The supporting structures must be provided with ladders and walkways for supervision and maintenance.

2.4 BELT CONVEYORS AND FEED CHUTE

Item no.: 6, 7, 8

Qty: 1 off, each

Intended use: to convey the predried bagasse from the dryer outlet to either the mill carrier or directly to the bale press. It must also be possible to divide the flow that some falls into the mill carrier and the rest flows to the bale press.

Capacity: up to 32 tons/h @ 38% m.c. Bulk density 70-80 kg/m^3.

Construction: the conveyors must be provided with sealed chutes at the charging and discharging ends to avoid formation of dust. Each conveyor must be equipped with a walkway along on one side. Conveyor (6) must be supported from the floor level.

Overall length:

item 6: 2 m

item 8: 8 m

The feed chute (7) must be equipped with adjustable flaps to guide the bagasse flow either back into the mill carrier or onto belt conveyor (8). It must also be possible to divide the flow so that one part falls into the carrier and the rest onto conveyor (8). The lower part of the chute must be designed to collect the excess bagasse from the lower deck of the mill carrier and discharge it onto conveyor (8).

2.5 BALE PRESS

Item no.: 9

Qty: 1

Intended use: to compress bagasse with m.c.'s varying between 25-50% to bales with a volume of 1.5 m^3 each with bagasse @ 35% m.c. Bulk weight of the loose bagasse approx. 70-80 kg/m^3. Expected bulk density of bale: 400 kg/m^3.

Capacity: up to 30 bales per hour of 1.5 m^3 each with bagasse at 35% m.c. Bulk weight of the loose bagasse is approximately 70-80 kg/m^3. Expected bulk density of bales: 400 kg/m^3.

Construction: made from welded and bolted structural steel. The press is equipped with a feed chute between the belt conveyor (8) and the compression chamber. The baling cycle must be activated automatically by means of a light barrier when the compression chamber is filled with loose bagasse. The ram is activated by a hydraulic system. The press must be provided with an adjustable automatic bale length measuring device. 4 binding wires must be tied automatically around each bale when the full length is reached. The tension pressure at the exit of the press must be adjustable. The press must be equipped with a device to form a bore of approx. 100 mm in diameter in the center of the bale to allow for the escape of heat and humidity when stored. The finished bales must be pushed to a line of approx. 5 bales on a guide channel before they are removed with a gripper.

2.6 GANTRY CRANE

Item no.: 10

Qty: 1

Intended use: to remove bales at the exit of the bale press and to place them either onto trailers or onto the intermediate storage area.

Capacity: lifting capacity: 1.5 ton. Maximum cycle: 30 bales per hour.

Construction: the gantry crane consists of a structural steel frame, a mobile bridge with 8 m span and an electric chain hoist with a gripping device. The gantry is 8 m wide, 12 m long and 6 m high. The bridge and the hoist are driven by electric motors that are controlled from floor level by means of a control unit hanging from the hoist. The electric power is fed via suspended cable and collector carriage. The ends of the runways are limited by means of puffers to avoid overriding.

III. EQUIPMENT SPECIFICATION FOR THE BALE STORE

3.1 TRACTOR AND TRAILERS

Item no.: 11

Qty: 1 Tractor and 2 Trailers

Intended use: to transport the bales from the bale press in the sugar mill to the bale store.

Capacity: each trailer must have a loading capacity of 20 tons and the tractor must be able to pull one trailer at a time.

Construction: the trailers must be of a sturdy flat bed design with pneumatic tires. Size of the platform: 6.2 m long x 2.4 m wide. The tractor must be equipped with a water-cooled diesel engine and it must be capable of pulling one trailer at a time over fairly flat terrain. Drive preferrably of the agricultural rear-wheel type. Attaching devices: adjustable rear twin tow hook and front draw bar.

3.2 MOBILE CRANE

Item no.: 12

Qty: 1

Intended use: to stack and unstack bales at the bale store. Stacking from flat bed trailers and unstacking onto Mac-type trucks.

Capacity: lifting capacity: 1 ton at 15 m reach and 15 m hook height.

Construction: The crane must be provided with a diesel engine and a 4 wheel drive system. All movements must be achieved by a hydraulic drive system; 4 hydraulically operated outriggers with levelling device to allow for fast dislocation. The hydraulic boom must be equipped with a gripping device suitable for bales with a size 2 m long x 1.02 m high x 0.76 m wide. The crane must be provided with working lights to allow for operation at night. It must be equipped with an overload safety device.

3.3 FIRE FIGHTING SYSTEM

Item no.: 14

Qty: 1 set

Intended use: to prevent further spread of a fire in case one stack starts by keeping the surfaces of the adjacent stacks wet.

Capacity: the system for the commercial scale pilot plant must be for 5 stacks of 850 tons each (35% m.c. basis).

Construction: the system must be designed in such a way that it can later be extended to the full scale as ultimately required for Constance. It consists of a central electric pump station, a net of distribution pipes, a set of fire-fighting equipment consisting of overfloor hydrants, hose reel cabinets with fire hoses, trailers for hoses with adjustable jet pipes, all with quick couplings. A modest fire alram system eith an alarm horn located in the guard house must be included. The detailed design should be awarded to a company specializing in fire-fighting techniques. Sizing of pump, pipes, hoses and jet nozzles are very important. Instructions on fire fighting techniques must be provided.

IV. EQUIPMENT SPECIFICATION FOR BALE BREAKING PLANT

4.1 GANTRY CRANE

Item no.: 16

Qty: 1 gantry with 2 cranes

Intended use: to unload bales from arriving trucks and trailers and to place them either into the intermediate bale store or directly onto the feed conveyor of the bale breaker.

Capacity: lifting capacity: 1.5 ton. Maximum cycle: 30 bales per hour for each crane.

Construction: the gantry crane consists of a structural steel frame, 2 mobile bridges with 8 m span each with an electric chain hoist and with a gripping device. The gantry is 8 m wide, 24 m long and 6 m high. Bridges and hoists are driven with electric motors that are controlled from the floor level by means of control units hanging from the hoists. Electric power is fed via suspended cables and collector carriages.

Puffers on the ends of the runways and between the bridges prevent collisions or overriding.

4.2 BALE BREAKER STATION

Item no.: 17

Qty: 1

Intended use: to disintegrate the bales and to feed the disintegrated bagasse onto a belt conveyor.

Capacity: up to 50 bales per hour @ 20-25% m.c. with 490-520 kg each bale i.e. approx. 25 tons/h.

Construction: the bale breaking station consists of bale feeding conveyor and bale breaker. The slat type feed conveyor is equipped with a variable speed drive to adjust the desired feed rate. Platforms along both sides of the conveyor allow easy removal of the binding wires. The conveyor is provided with supports to the floor level. The bale breaker is a welded construction made from heavy mild steel plates. The drum-type rotor is provided with exchangeable steel teeth. The rotor shaft is supported with grease lubricated spherical roller bearings. Two flywheels avoid shock loads on the motor. The rotor is driven by an electric motor via a v-belt drive with one of the flywheels serving as a v-belt pulley. One section of the top housing is provided with hinges to allow easy access to the teeth of the rotor. The entrance of the breaker is a guide tunnel to avoid having the wireless bales fall apart before reaching the rotor. The disintegrated bagasse falls through a coarse screen in the bottom of the breaker. The bale breaker sits on a concrete foundation. The upper section is provided with a dust exhaust hood.

4.3 MAGNETIC SEPARATOR

Item no.: 18

Qty: 1

Intended use: to remove wire pieces that were overlooked by the operator in front of the bale breaker.

Capacity: pick-up height between belt and magnet 200 mm, belt speed up to 2 m/s, thickness of bagasse layer up to 150 mm.

Construction: permanent type magnet supported on a frame from the floor level. The magnetic block must be moveable sideways for easy removal of wire pieces. The space between the belt conveyor and the magnet must be adjustable.

4.4 DUST EXTRACTION SYSTEM

Item no.: 19

Qty: 1

Intended use: to extract the dust from the bale breaker and to deposit it back onto the belt conveyor.

Capacity: approx. 5'000 m^3/h of air.

Construction: the extraction system consists of conveying pipe, high efficiency cyclone separator, rotary valve at bottom of cyclone and extraction fan with discharge pipe at top of cyclone. The parts are made of mild steel metal sheet. The cyclone must be provided with supported to the floor level.

4.5 BELT CONVEYOR

Item no.: 20

Qty: 1

Intended use: to collect the disintegrated bagasse from underneath the bale breaker and to convey it into the existing boiler feed carrier.

Capacity: up to 25 tons/h of bagasse with 20-25% m.c. and a bulk density of 60-75 kg/m^3 i.e. approx. 400 m^3/h.

Construction: The conveyor must be provided with dust-tight chutes at the charging and discharging end. It must be equipped with a walkway along all of one side. It must be supported from floor level. Overall length: 20 m.

4.6 HYDRAULIC PRESS FOR SCRAP WIRE

Item no.: 21

Qty: 1

Intended use: to compress the wires that were removed from the bales into packages for sale to a scrap metal dealer.

Capacity: up to 300 kg/h of waste wire with 2.8 mm diameter, tensile strength of wire 50 kg/mm^2. Weight of compressed packages approx. 40-50 kg.

Construction: the hydraulic press should be moveable on wheels. It must be equipped with an electric drive and a hydraulic system. The compression chamber should be 1 m long, 0.4 m high. The compression chamber cover must also move hydraulically. The knife edges and the walls of the compression chamber must be provided with exchangeable wear plates.

LIST OF RECOMMENDED VENDORS

BELT CONVEYORS
Jost Brothers AG., CH-3527 Heimberg, SwitzerlandHEFO AG., CH-4222 Zwingen, Switzerland

FLUE GAS DUCT, GENERAL STEELWORK
Forges Tardieu, Port Louis, Mauritius

ROTARY DRUM DRYER
SWISSCOMBI W. Kunz AG., DH- 5606 Dintikon, Switzerland

BALE PRESS
American Baler Co., Carl O. Goettsch Company, Cincinnati, Ohio 45202

GANTRY CRANE (CHAIN HOISTS)
R. Stahl, D-7000 Stuttgart 1, West Germany

FLAT BED TRAILERS
W. Stocklin AG., CH 4143-Dornach, Switzerland

MOBILE CRANE
Eder GmbH., D-8302 Mainburg, West Germany

FIRE FIGHTING SYSTEM
Jomos Feuerloschtechnik AG., CH-8032 Zurich, Switzerland

BALE BREAKER
Condux-Werk KG., D-6451 Wolfgang bei Hanau, West Germany

MAGNETIC SEPARATOR
Swisstool AG., CH-8021 Zurich, Switzerland

DUST EXTRACTION SYSTEM
Ventilator Stafa AG., CH-8712 Stafa, Switzerland

WASTE WIRE PRESS
Maschinenfabrik E. Back & Co. KG., D-5900 Siegen, West Germany

RECOMMENDED TEA INDUSTRY ENERGY EFFICIENCY/SUBSTITUTION ANALYSIS

Introduction and Background

Energy Sector Overview and Strategy

Mauritius' commercial energy requirements are met in roughly equal parts by indigenous bagasse and imported petroleum products, although these two fuels are consumed in very different ways. Bagasse, a by-product of the sugar industry, is used almost exclusively to meet the energy needs of that industry; its contribution as a direct energy source to the rest of the country is very small. The energy requirements of the remainder of the economy are met primarily (about 90 percent) from imported petroleum products, supplemented by a small amount of hydroelectricity and imported coal.

The crux of Mauritius' energy problem and, the principal focus of the Energy Assessment Report prepared in 1981, 1/ is how to reduce the bill for imported oil, which grew from $10 million in 1973 to nearly $60 million in 1980, since when it has slightly declined. The key to achieving this objective, the Assessment noted, lay in a program to improve the very low efficiency with which the sugar industry utilizes bagasse to generate steam and electricity. These improvements would allow the sugar mills to produce more surplus bagasse, which could then be used to generate electricity for the rest of the economy and as a substitute for imported fuels.

Based on these improvements in bagasse energy production, as well as a modest, but sustained effort to improve the efficiency of energy use in all sectors of the economy, the Assessment outlined an "Accelerated Energy Program" which would enable the country to reduce its dependence on oil imports from 90% of commercial energy in 1980 to about 60% by 1990.

Energy Efficiency and Fuel Substitution in the Tea Industry

The tea industry is one of the most promising industrial candidates for achieving significant fuel oil savings because energy efficiency is low, energy costs are a large proportion of operating expenses, and the oil-burning boilers currently used for raising heat to wither and dry tea can be modified to burn substitute fuels. The industry produces about 8000 tonnes of tea per year in 8 factories, each tonne of which requires 35 GJ of heat energy for withering and drying.

1/ Mauritius: Issues and Options in the Energy Sector, December 1981, Report of the Joint UNDP/World Bank Energy Assessment Program (No. 3510-MAS)

280,000 GJ are required annually, equivalent to 6700 tonnes of fuel oil, costing $1.7 million. The actual use of imported oil is in fact somewhat less as at least three factories are burning some bagasse instead.

The international target for energy use in withering and drying tea is 10 GJ/ton for fuel oil and 20 GJ/ton of biomass, as opposed to the industry's current consumption of 35 GJ/ton. There is thus substantial potential for energy saving from an appropriate combination of energy efficiency improvements and the substitution of lower-cost fuels, such as bagasse, for oil.

To realize these potential energy savings, a plant-by-plant audit of current energy use patterns, the scope for efficiency improvements and the alternative means of reducing energy costs is required. It would build on a preliminary review by the Ministry of Energy and Internal Communications. Based on this analysis, a costed and prioritized program of recommended energy efficiency improvements, including no cost/low cost housekeeping changes and investments in plant modifications or replacement would be prepared. The investments would be brought to pre-feasibility status and potential vendors identified. Finally, the impact of the recommended program on the demand for different fuels and on the balance of payments would be quantified.

Objectives

The goal of the activity is to evaluate the potential for improving energy efficiency in the tea industry and to recommend the most cost-effective package of energy efficiency improvement measures in each Mauritian tea factory. In specific terms, the principal objectives are:

(a) to identify means by which an immediate improvement in energy efficiency in tea withering and drying can be achieved, with minimal (low/no cost) investments, through the application of improved housekeeping, maintenance techniques, minor layout changes, better instrumentation, operational control, etc.;

(b) to identify economic and financially justifiable means by which improvements in combustion and heat transfer and in motive power can be achieved through investment in significant plant modification and rehabilitation or with new plant;

(c) to identify cost-effective boiler modifications and substitute fuel storage systems which would allow each factory to convert from fuel oil to bagasse or other more economic fuels; and

(d) based on the economic cost of alternative fuels and their relative combustion efficiencies, to calculate the economic and financial costs and benefits of the alternative conservation and conversion measures, recommend an optimal package of such measures for each factory, and quantify the energy and foreign exchange savings that will result.

Scope of Work

This activity will require the services of an energy audit engineer who has experience with the tea industry and with biomass combustion, and an energy economist. The auditor and economist will visit each tea factory to identify and evaluate opportunities for energy conservation and substitution of oil with baled bagasse and other fuels. This work can be divided into four tasks: (1) energy efficiency audits; (2) identification of energy efficiency improvements; (3) identification of potential energy substitution measures; and (4) economic analysis and prioritization of alternatives.

Task 1: Energy Efficiency Audits. This will consist of:

(a) collection of data on the types of energy-using equipment currently in operation in the eight plants and their technical specifications/performance characteristics; and

(b) review of existing processes and the efficiency of energy use in each plant.

Statistics and data regarding factory throughput, machinery, performance and operating costs are available from the Mauritius Tea Development Authority (MTDA) and from the technical management of the private sector tea processors.

Task 2: Identification of Energy Efficiency Improvements. This will involve identifying energy efficiency measures involving: (a) low/no cost changes; and (b) conservation measures requiring larger-scale investments. The possible options for improved energy utilization in tea drying that would be evaluated include:

(a) combustion efficiency improvements;

(b) improved heat transfer efficiency (whether steam/air or direct air heaters);

(c) improved steam efficiency, including optimization of heat transfer and condensate recovery;

(d) improved air mass flow including optimization of fan efficiencies for the head/flow operating regime; and

(e) in cases where bagasse is presently used, improved fuel preparation prior to combustion.

These analyses should identify low cost energy savings, based on conservation measures that can be taken almost immediately, with minimum engineering input and capital investment. These typically show a simple payback of under one year. They would include minor changes in layout, improved fuel preparation, better maintenance, tighter operational control, corrective improvements to steam circuits and air-fuel ratios, and improved housekeeping, staff education and training. They would also identify more substantial investments which promise an acceptable economic rate of return, i.e., at least 15%. Such measures might include the introduction of new and more efficient combustion equipment and/or heat exchangers, and possibly the introduction of innovative equipment, such as gasifiers.

Task 3: Identification of Potential Cost-saving Energy Substitution Measures. This will entail identifying the technical modifications, managerial changes, training needs and storage requirements for conversion from fuel oil to baled bagasse or other more economic fuels in each factory where such conversion appears to be justified. In such cases, the consultant will prepare preliminary designs and costings for the civil, electrical and mechanical works required to receive, store, retrieve and combust the lower-cost fuel.

Task 4: Economic Cost/Benefit Analysis. Based on estimates of the economic and financial cost of alternative fuels, an evaluation will be made of the costs and benefits of each potential efficiency improvement and conversion investment. Improvements and conversion measures in each mill will be ranked in descending order of cost effectiveness and a recommended package of measures specified. The aggregate impact of these measures on energy consumption by fuel type and on the balance of payments will be quantified.

Organization and Cost

The analysis will be performed by an energy auditor and an economist, working under ESMAP supervision. The energy auditor will arrive first in Mauritius and will spend 20 working days (2 days per factory initially, plus briefing and wrap-up) gathering performance data and conducting energy audits. Halfway through his stay, the economist will arrive for 10 working days to undertake the economic analysis. Once home, the economist will have 10 working days to prepare his report, which will be forwarded to the energy auditor. He will have 15 working days to complete his analyses and compile it and other consultant's work into a single document.

The total cost of consultant services will be not more than US$44,000, as detailed below:

Table 1: CONSULTANT BUDGET

Item	Staff-days	Cost (US$)
A. Fees		
-Energy auditor	20 (field) + 15 (home) + 4 (travel)	15,600
-Economist	10 (field) + 10 (home) + 4 (travel)	7,200
Sub-total		22,800
B. Per diem		
-Energy auditor	22	1,716
-Economist	12	936
Sub-total		2,652
C. Travel		7,800
D. Auditing equipment		1,000
E. Miscellaneous/contingency		2,000
Sub-Total		36,252
F. ESMAP Costs		
-per diem	12	936
-travel		3,900
-staff time	24	2,500
Sub-Total		7,336
Total		43,588

Source: Mission estimates.

Staff of the UNDP/World Bank Energy Sector Management Assistance Program (ESMAP) will provide technical supervision of the consultants, including review of and assistance with revisions to the report. The cost of this supervision, to be provided jointly for this and the proposed surplus Bagasse Production project, has been included in the cost estimate.

The consultants will be supplied with background data and relevant reports, such as the MEIC report on energy efficiency in the tea industry and the ESMAP document on bagasse handling. In-country work will be expedited because of the quality and accessibility of relevant information in Mauritius. The MTDA Energy, and the Ministries of Agriculture and Industry will assist the consultants in advance and during their fieldwork by securing active cooperation of the management and senior technical staff of each tea factory, scheduling appointments, and offering technical and practical assistance in the execution of fieldwork and the preparation of the draft report. Close liaison with the MEIC will be essential in view of their interest and activity in this area.

Consultants' Terms of Reference

The energy auditor will be responsible for the following:

(a) collecting available data on existing equipment, technical specifications, performance characteristics and energy consumption in the tea industry;

(b) conducting energy efficiency audits and boiler conversion reviews for each of the eight tea factories, including a series of measurements of energy utilization and combustion efficiency;

(c) identifying potential energy efficiency improvements, including low/no-cost process changes, investment in more efficient energy-using equipment and investment in fuel-substitution conversions;

(d) provide design drawings, technical specifications and a list of recommended vendors for those investments;

(e) advise the economist on the foreign and local capital and operating costs of any recommended investments and process changes and the expected fuel oil savings that will result;

(f) review plans for and prepare similar recommendations for any proposed new tea factories;

(g) outline the training needs, managerial requirements and time scale for implementation of the above recommendations; and

(h) in consultation with the economist, prepare the final report.

The economist will undertake the following tasks:

(a) estimate the economic and financial cost of alternative fuels appropriate for use in the tea industry;

(b) compile the foreign and local capital and operating costs of potential energy efficiency improvements and conversion measures at each tea plant, based on assumed operating lifetimes;

(c) rank the potential investments at each factory, in descending order of economic cost-effectiveness;

(d) specify and calculate the economic and financial costs and benefits of the optimal investment package at each plant, including IRRs and NPVs over a range of possible discount rates; and

(e) in consultation with the energy audit consultant, prepare a disbursement schedule for an industry-wide set of investments.

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

Activities Completed

Project Formulation and Justification

Panama	Power System Loss Reduction Study	June, 1983
Zimbabwe	Power System Loss Reduction Study	June, 1983
Sri Lanka	Power System Loss Reduction Study	July, 1983
Malawi	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry	November, 1983
Kenya	Power System Efficiency Report	March, 1984
Sudan	Power System Efficiency Study	June, 1984
Seychelles	Electric Power System Efficiency Study	August, 1984
The Gambia	Solar Water Heating Retrofit Project	February, 1985
Bangladesh	Power System Efficiency Study	February, 1985
The Gambia	Solar Photovoltaic Applications	March, 1985
Senegal	Industrial Energy Conservation Project	June, 1985
Burundi	Improved Charcoal Cookstove Strategy	September, 1985
Thailand	Rural Energy Issues and Options	September, 1985
Ethiopia	Power System Efficiency Study	October, 1985
Burundi	Peat Utilization Project	November, 1985
Botswana	Pump Electrification Prefeasibility Study	January, 1986
Uganda	Energy Efficiency in Tobacco Curing Industry	February, 1986
Indonesia	Power Generation Efficiency Study	February, 1986
Uganda	Fuelwood/Forestry Feasibility Study	March, 1986
Sri Lanka	Industrial Energy Conservation: Feasibility Studies for Selected Industries	March, 1986
Togo	Wood Recovery in the Nangbeto Lake	April, 1986
Rwanda	Improved Charcoal Cookstove Strategy	August, 1986
Ethiopia	Agricultural Residue Briquetting Pilot Project	December, 1986
Ethiopia	Bagasse Study	December, 1986
Peru	Proposal for a Stove Dissemination Program in the Sierra	February, 1987
Rwanda	Improved Charcoal Production Techniques	February, 1987
Kenya	Solar Water Heating Study	February, 1987
Indonesia	Energy Efficiency Improvement in the Brick, Tile and Lime Industries on Java	March, 1987
Malaysia	Sabah Power System Efficiency Study	March, 1987
Côte d'Ivoire	Improved Biomass Utilization--Pilot Projects Using Agro-Industrial Residues	April, 1987
Mauritius	Power System Efficiency Study	May, 1987
Botswana	Tuli Block Farms Electrification Pre-feasibility Study	July, 1987
Sudan	Energy Forestry Project	July, 1987
Ghana	Sawmill Residues Utilization Study	July, 1987
Thailand	Accelerated Dissemination of Improved Stoves and Charcoal Kilns	September, 1987

Institutional and Policy Support

Sudan	Management Assistance to the Ministry of Energy and Mining	May, 1983
Burundi	Review of Petroleum Import and Distribution Arrangements	January, 1984
Papua New Guinea	Energy Sector Institutional Review: Proposals for Strengthening the Department of Minerals and Energy	October, 1984
Papua New Guinea	Power Tariff Study	October, 1984
Costa Rica	Recommended Tech. Asst. Projects	November, 1984
Uganda	Institutional Strengthening in the Energy Sector	January, 1985
Guinea-Bissau	Recommended Technical Assistance Projects in the Electric Power Sector	April, 1985
Zimbabwe	Power Sector Management Assistance Project: Background, Objectives, and Work Plan	April, 1985
The Gambia	Petroleum Supply Management Assistance	April, 1985
Burundi	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987)	May, 1985
Liberia	Recommended Technical Assistance Projects	June, 1985
Burkina	Technical Assistance Program	March, 1986
Senegal	Assistance Given for Preparation of Documents for Energy Sector Donors' Meeting	April, 1986
Zambia	Energy Sector Institutional Review	November, 1986
Jamaica	Petroleum Procurement, Refining, and Distribution	November 1986
Botswana	Review of Electricity Service Connection Policy	July, 1987