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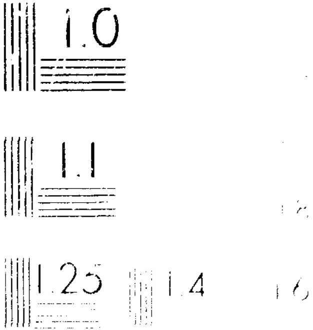
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19th January 1982

Mr D Gardellin
Officer-in-Charge
Purchase and Contract Service
UNIDO
P O Box 300
A-1400 Vienna
AUSTRIA

Dear Mr Gardellin,

I have pleasure in enclosing with this letter the Final Report on Mauritius Sugarcane By-products which we have prepared jointly with the Tropical Products Institute of London.

We have appreciated the opportunity to work both with the Government of Mauritius and UNIDO on this project and are grateful for the support we received in Mauritius.

We confirm our interest in working with UNIDO in any other opportunities which may arise.

Yours sincerely,

F L Cockcroft
Manager - Consultancies
General Agriculture Division

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

Volume 1

MAIN REPORT

Units and Technical Abbreviations

bar A	measure of absolute pressure (1 bar A is effectively 1 atmosphere)
brix	weight of solids % weight of solution
BOD	biological oxygen demand
¢	cent
C	Centigrade
cif	cost, insurance and freight
COD	chemical oxygen demand
CP	crude protein
cumec	cubic metre/second
d	day
DM	dry matter
fcf	fresh, chilled and frozen
fob	free on board
gal	Imperial gallon
GL	Gay Lussac (100°GL is 100% alcohol)
GWh	Gigawatt-hour
GNP	Gross national product
g	gram
ha	hectare
hr	hour
IRR	Internal Rate of Return
kg	kilogram
kJ	kilojoule
km	kilometre
kWh	kilowatt-hour
ℓ	litre
lb	pound
m	metre
m^2	square metre
m^3	cubic metre
M	Million
ME	Metabolisable energy
MJ	megajoule
MSG	Monosodium glutamate
MW	megawatt
NCV	net calorific value
NFE	Nitrogen free extract
NPV	Net present value
Rs	Mauritius Rupees
t	tonne
tc/d	tonnes cane per day
tc/hr	tonnes cane per hour
t/ha	tonnes per hectare
y	year

Institutions

ACP	Lomé Convention countries of Africa, the Caribbean and the Pacific
A&M	Alcohol and Molasses Export Company Limited
ADB	African Development Bank
AMB	Agricultural Marketing Board
CCCE	Caisse Centrale pour la Cooperation Economique (Paris)
CEB	The Central Electricity Board
CSA	Commonwealth Sugar Agreement
DBM	Development Bank of Mauritius
FAO	Food and Agriculture Organisation of the United Nations
IBRD	International Bank for Reconstruction and Development (World Bank)
IDA	International Development Association (World Bank)
ISO	International Sugar Organisation
MCAF	Mauritius Cooperative Agricultural Federation Limited
MCCB	Mauritius Cooperative Central Bank Limited
MCGA	Mauritius Cane Growers Association
MM	Mauritius Molasses Limited
MMA	Mauritius Meat Authority
MMPA	Mauritius Meat Producers Association
MRC	Mauritius Research Council
MSCPA	Mauritius Sugar Cane Planters Association
MSS	The Mauritius Sugar Syndicate
MSPA	Mauritius Sugar Producers Association
MSIRI	Mauritius Sugar Industry Research Institute
ODA	Overseas Development Administration (London)
PROSI	Public Relations Office of the Sugar Industry
U of M	University of Mauritius
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organisation
UNCDF	United Nations Capital Development Fund

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

NOTES ON EXCHANGE CONVERSIONS AND LOCAL UNITS

Exchange conversions

Costs are based on those at 1 July 1981. Exchange rates are those after the devaluation in October 1981

ie	US$1 = Rs10.25
	£1 = Rs19.00

The devaluation during report writing has made cost estimation particularly difficult. The foreign exchange components have been converted at the new rates. However, it is not possible to make accurate new estimates of all local costs, given that the devaluation would eventually affect some, but not all. For example, the cost of steam in the sugar factories would probably not be affected, but that of electricity would increase to the extent that imported fuel is used to generate it.

Conversion rates in the other Appendices are historical,

ie	October 1979 - October 1981	US$1 = Rs8.67
	January 1977 - September 1979	US$1 = Rs6
	Sugar crop season 1979/80 (average)	US$1 = Rs7.335

Costs before 1977 have not been converted to dollars. The figures for Universal Board Company Limited in Appendix 3 are based on historical costs (and not converted to dollars) or on operating costs prepared by the liquidators and based on the July 1981 rate of US$1 = Rs8.67.

(Appendix 11)

Local units

1 arpent	=	1.043 acres = 0.422 ha
1 foot	=	0.3048 metres
1 pound (lb)	=	0.4536 kg
1 gallon	=	4.546 ℓ

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

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CONTENTS (cont)

1. EXECUTIVE SUMMARY

Present situation

1. Mauritius is effectively a single crop economy with sugarcane grown on 88% of the land under cultivation and the sugar industry accounting for 32-53% of GNP in the 1970s. Productivity of sugarcane/ha is relatively high and the industry is a world leader in interline cropping. Constraints on increasing production are land suitable for sugarcane, water and the length of the harvesting season.

2. There are at present 21 sugar factories with capacities varying from 60-240 tc/hr. Processing is efficient by world standards but performance is declining. In average non-disaster years in the 1970s sugar production was 687 000 t/y; it is estimated to rise to 715 000 t/y in 1990.

3. Average production of sugarcane by-products in the same years was 1.27 M t/y of cane tops, 211 000 t/y of filter mud, 191 000 t/y of molasses at 86° brix and 1.73 M t/y of bagasse. By 1990 these are estimated to increase to 1.32 M t/y, 220 000 t/y, 199 000 t/y and 1.8 M t/y respectively.

4. Domestic sales of sugar average 40 000 t/y; the remainder (94%) is exported. Present uses of sugarcane by-products are: approximately 8% of cane tops are used as a feed by the livestock industry; almost all filter mud is used as a fertiliser; 6 000 t/y of molasses is used for animal feed, 15 000 t/y in three distilleries and the remainder exported (170 000 t/y in non-disaster years); and most of the bagasse is burnt in sugar factory boilers to power the factories, with surplus bagasse generating electricity for export to the national grid (47.8 GWh/y in late 1981). Chapter 2 describes the present situation in greater detail.

Technical options and market analyses

5. The large number of technical options available for utilisation of sugarcane by-products are detailed in Chapter 3, as are international and national market analyses in Chapter 4. The latter include: sugar; molasses; fermentation and distillation products from molasses such as ethanol, baker's yeast, fodder yeast, citric acid, monosodium glutamate and ethylene; products from bagasse such as charcoal, pulp and paper, particle board and furfural; sugarcane wax from filter mud; and livestock products (primarily milk, beef and venison).

A strategy for the development of by-product industries

6. The technical viability of the options available and the market considerations of the products have been used to select those processes for and uses of sugarcane by-products recommended for further study. These are listed in Chapter 5.

7. The principal contribution that sugarcane by-products can make to the economy of Mauritius is the production of energy. Sugarcane is one of the world's most effective crops at converting solar energy to biomass. Two major projects, the production of ethanol from molasses and of electricity from surplus bagasse have been proposed, as has a minor energy project - the production of charcoal from bagasse.

8. There is also an economic and a social need to develop the livestock industry and to expand its use of sugarcane tops and by-product feeds. A series of relatively small projects concerned with the development of livestock feeds is therefore proposed.

9. There are advantages in siting the industrial processes at specific sugar factories, and the livestock projects on sugar or other estates which raise livestock, at livestock cooperatives or at feed mills. To site all projects in one agro-industrial complex would not be a rational use of resources.

10. In order to ensure that the proposed projects are conducted in the most efficient and economic manner it will be necessary to mobilise the country's technical expertise and more fully employ the services of the Mauritius Sugar Industry Research Institute (MSIRI) and individuals within the University of Mauritius (U of M) and the sugar industry.

11. On account of the multiplicity of options and the sometimes conflicting economic interests of potential users of sugarcane by-products, it is essential that institutions be developed to enable Government to plan in a rational manner the exploitation of the sugarcane by-product resources.

12. It is therefore suggested that the proposed Mauritius Research Council (MRC) be established as soon as possible and be authorised to exercise overall direction of the investigation and feasibility phases of the proposed projects; and that in view of the importance and complexity of energy problems a Central Energy Planning Committee (CEPC) be also established. The activities of both MRC and CEPC should be coordinated by an Authority

constituted at the very highest level in Government. This Authority would advise Government as to how funds required for financing the programme should be secured, what funds should be allocated for direction by MRC and CEPC and as to how mixed public/private enterprises (such as will be required for producing electricity from bagasse) should be organised, funded and controlled.

Project proposals

13. The projects proposed are described and costed in Chapter 6.

14. Energy projects: ethanol from molasses Technology for the production of anhydrous ethanol is well established. The decision by Government as to whether a plant should be established to produce ethanol for fuel purposes will depend partly on economic and financial factors - the relation between the export price of molasses and the import price of gasoline - and partly on non-economic considerations. Three alternative methods of producing ethanol have been examined. These are:

Option A	A 107 000 ℓ/d distillery operating during the sugar crop season only
Option B	A 50 000 ℓ/d distillery operating 300 d/y
Option C	A 30 000 ℓ/d extension of the existing Beau Plan distillery.

Either Option A or B would produce sufficient ethanol annually as a constituent of an acceptable motor fuel to replace 20% of the gasoline used in Mauritius. Option A is more attractive in financial terms. The total capital cost of the 107 000 ℓ/d distillery would be Rs122 M ($11.9 M) and operating costs after the first year would be Rs46 M ($4.5 M)/y. The gasoline companies' capital costs would be Rs3 M ($0.3 M), and extra operating costs would be Rs0.26 M ($25 000)/y.

15. A major problem of ethanol production is the disposal of vinasse, an unpleasant effluent; a 107 000 ℓ/d distillery produces 1 500 m^3/d. It is assumed that it will be so located as to be able to feed its vinasse into an irrigation system. However this may not be possible, and there is an urgent need to evaluate alternative methods of disposal. Anaerobic digestion is considered one of the more attractive in terms of its energy ratio. It is therefore recommended that a pilot plant for anaerobic digestion of vinasse be established at the Beau Plan

distillery. The cost of this pilot plant would be Rs7.0 M ($0.68 M). The cost of an anaerobic digestion plant for the 107 000 l/d distillery would be Rs27 M ($2.7 M); it would give a saving in operating costs of Rs1 M ($0.1 M) y.

16. <u>Energy projects: electricity from bagasse</u> Three steps concerned with electricity production from bagasse are proposed; they form part of an integrated approach to the problem and include the projects listed in the text.

a) <u>Improvements in energy efficiency at the sugar factories</u> Further investment in the process sections of the 15 larger sugar factories is required in order to optimise the production and utilisation of steam and hence provide an increased surplus of bagasse. This project would cost Rs11.43 M ($1.15 M)

b) <u>Pelleting of bagasse</u> There are two levels of alternatives for the generation of electricity using surplus bagasse. The first alternatives are: (i) generation during the sugar crop season only; (ii) generation year-round. The maximum available electrical energy production from bagasse in the crop season only is 160 GWh; year-round it is 229 GWh. The second alternative is economically more attractive but is possible only if bagasse can be compressed and stored. A feasibility study is required to ascertain the most economic method of pelleting bagasse. This study would cost Rs646 000 ($63 000) and would be followed by the establishment of a pilot pelleting plant at a sugar factory where there is a surplus of bagasse, at a cost of Rs29 M ($2.8). The capital cost of equipping 15 sugar mills with pelleting plant is estimated at Rs307 M ($30 M).

c) <u>Generation of electrical energy using pelleted bagasse</u> Assuming year round operation, at the second level of alternatives the following three options have been examined.

Option A	A bagasse fired central power station (30 MW - 229 GWh)
Option B	Regional bagasse fired power stations at three sugar factories using high presssure boilers (26 MW - 201 GWh)
Option C	Increased power generation at three sugar factories using existing boilers (24 MW - 182 GWh)

Option C is recommended because its capital and operating costs/KWh are lower than with the other options. The project cost would be Rs 80 M ($7.8 M).

17. <u>Energy projects: charcoal from bagasse</u> A feasibility study of the possibility of producing charcoal from bagasse is recommended. This would cost Rs384 000 ($37 000). If the study recommends a pilot plant, it should be established at a sugar factory where an adequate surplus of bagasse exists. The cost of this project would be Rs16.4 M ($1.6 M).

18. <u>Livestock feed projects</u> A series of relatively small livestock feed projects are proposed. It is suggested that those concerned primarily with farming practice should be carried out by the Ministry of Agriculture and Natural Resources and the Environment whilst those concerned primarily with agro-industrial technology should be conducted by MSIRI and/or U of M. It is proposed that a livestock production expert be employed for two years to provide on-site advice to producers; he would supervise the feed projects and extend their results to the commercial sector, and he would be responsible for finalising the work of the FAO/UNDP livestock project. The projects, together with estimated costs, are listed below.

Project	Agency	Estimated Total Cost Rs'000	($'000)
<u>Utilisation of cane tops</u> (Collection in field; effect of ripeners and fire; utilisation fresh or ensiled)	Ministry of Agriculture	439	(43.4)
<u>Utilisation of molasses</u> Low level for ruminants: higher levels for non-ruminants and use in blocks	Ministry of Agriculture		
<u>Utilisation of filter mud</u> Wet feeding; as substitute for imported trace elements	Ministry of Agriculture	219	(21.4)
<u>Alternative methods of treating bagasse to improve nutritive value.</u> A technical assessment of alternative treatment methods followed by installation of most suitable pilot plant	MSIRI/U of M	573	(55.9)
<u>Extraction of protein from sugarcane juice.</u> Evaluation of technical and economic factors	MSIRI/U of M	1 236	(120.4)
<u>Livestock production expert</u>	MRC	1 540	(150.0)

19. Two other minor projects are recommended. The first is technical assistance to help the older distilleries improve their productivity. The cost would be Rs72 000 ($7 000). The second is technical assistance to the particle board factory at St Antoine if it reopens. The cost would be Rs384 000 ($37 500).

Summary of project costs

20. Total project costs are as follows:

	Foreign exchange costs	Local costs	Total
Rupees Million:			
a. Investigational work, feasibility studies, pilot plants, improvements to sugar factories, and technical studies	61	8	69
$ Million	5.0	0.7	6.7
b. Major projects			
Ethanol (excluding vinasse digester)	92	33	125
Electricity	352	35	387
	444	68	512
$ Million	43.4	6.6	50.0

21. Terms of reference for the feasibility studies of bagasse pelleting and charcoal production, and of the livestock studies are provided at the end of this volume.

Funding

22. Detailed recommendations as to possible methods of funding the projects are made in Chapter 6. The Ministry of Agriculture's component of livestock feed projects might be partially funded by UNDP as a final phase of the current

FAO/UNDP livestock project whilst the MSIRI U of M component could be funded as a UNIDO project if UNDP country programme funds are available. It is proposed that the livestock production expert is funded by a two year extension to the FAO/UNDP project. Improvements in the efficiency of the older distilleries and technical assistance to the particle board factory could be funded under a multilateral or a bilateral technical assistance programme. It is suggested that as the feasibility studies and the pilot plants would be of interest not only in Mauritius but also in many other sugar producing countries, UNIDO might consider seeking funding from regional or global UNDP funds. Improvements in the process sections of the 15 sugar factories could be funded by special loans from the Development Bank of Mauritius (DBM). The ethanol plant and the equipment of sugar factories with pelleting plant and generating equipment are major and complex projects and would have to be financed in what Government considers to be the most appropriate manner. Possibly a consortium of multilateral (IBRD, ADB) and private banks would channel funds through DBM.

Justification and benefits

23. Chapter 7 describes the project justifications and benefits. The projects under the first heading in the previous paragraph have benefits that cannot be quantified nor related to their costs; they are however necessary if the by-products sector is to develop, and there are directly related to the major projects. Others are concerned with the livestock sector, and would contribute to its growth. The exception is the improvements to the sugar factories, whose costs are included in the analyses of electricity production.

24. The chosen options of the major projects have returns as follows:

	IRR
Ethanol Option A	7.8%
Electricity Option C	26.4%

Constant July 1981 prices have been used, with account being taken of the subsequent devaluation of the Mauritius rupee. In the ethanol projections it has been assumed that prices of gasoline and molasses will increase 3% /y; at constant prices the return on Option A is 1.1%. The economic rates of return are:

	Economic return
Ethanol Option A	8.5%
Electricity Option C	24.9%

25. Although the use of the vinasse digester appears attractive in energy terms, it is less so financially since the methane replaces cheap factory steam. The IRR of the ethanol plant with a vinasse digester is 6.8%.

26. The investment in the bagasse pelleting plants shows high rates of return over coal firing:

	IRR
Option A vs coal	23.6%
Option B vs coal	34.4%

The increase in capital from coal firing to Option B is so small that the IRR is extremely high.

Conclusions

27. It is recommended that the studies under the first heading of paragraph 20 be started as soon as possible. The electricity project should proceed as soon as the preliminary work has shown satisfactory results. The ethanol project should be deferred until the price relationship is more in its favour. This may happen in the 1990s; the IRR on a plant built in 1990 is 12.5%.

28. Detailed information is provided in the 12 Appendices in order to give the widest possible informative background for a study of the project proposals. There is detailed cross-referencing in the main report to the relevant information in the Appendices.

2. PRESENT SITUATION

The role of the sugar industry in Mauritius

2.01 Mauritius is effectively a single crop economy, with the sugar industry accounting for 32-53% of GNP in the 1970s. Sugar is also an important source of government revenues. It is grown on 88% of land under cultivation, and on 46% of the island's surface. Production in 1971-80 averaged 637 000 t sugar, with a maximum of 718 000 t in 1973.

2.02 Productivity of sugarcane/ha is relatively high and its processing is efficient by world standards. The island is at latitude 20°S, unfortunately in the Indian Ocean cyclone track, and the crop is likely to be devastated at fairly frequent intervals. Between 1971 and 1980 there were two cyclone years (1975 and 1980) and one drought year (1971). In the two cyclone years cane production was about 30% lower than the average of the more favourable years in the decade, and in the drought year it was about 15% down. Fortunately sugarcane is a crop which is able to regenerate relatively quickly after natural disasters. Average production in the non-disaster years was 687 000 t. Appendix 1 describes the sugar industry and includes a selection of available data.

Sugarcane production (with interline cropping)

2.03 The sugarcane cycle in Mauritius consists of a plant crop normally followed by at least 8 ratoons. The planting of the cane may either be "petite saison" or "grande saison". Petite saison planting involves harvesting the final ratoon crop early in the crop season, and replanting immediately for harvest at the end of the following crop season. With grande saison planting, the final ratoon crop is harvested, usually towards the end of the crop season, and replanted out-of-crop for harvesting the next crop but one. Yields of grande saison cane are 8% to 40% higher than petite saison, depending on location. Petite saison appears more profitable, but grande saison constitutes 65% of land planted (1979). The principal constraint on petite saison is the availability of machinery and labour for preparing the land as these are already mainly committed to the harvest.

2.04 Although not in a position to plant the major part of their cane in the petite saison, Mauritian producers make considerable efforts to improve the productivity of their cane land by other means. Indeed, this happens on a scale seldom seen elsewhere. It takes three forms:

- grande saison land may be prepared some months before planting, and another crop grown in the intervening period;

- during the first few ratoons other crops may be grown in the cane interlines before the cane canopy forms; and

- after the final ratoon has been cut and before grande saison replanting, a short duration ratoon may be grown to be used as fodder cane, which will be cut in a suitable state for animal feed use before land is prepared for replanting: yields are around 30 t/ha in drier areas where irrigation is available.

2.05 The constraints on the production of cane are land, water and the length of the harvesting season. Very little additional land suitable for sugarcane production is available. About 5% of the cane land is covered by boulders and in many fields these have been heaped into rows or pyramids. The removal of these boulders is both expensive and energy intensive; in many fields it would not be economic. However, destoning is being carried out, usually before cane planting, not only to increase the area under cane but also to facilitate subsequent mechanical operations.

2.06 The area of cane under irrigation is 20% of the total. Under new schemes, of which the Northern Plains is the most significant, another 2% will come under command by the end of 1982. However, water is a constraint and the land area where full irrigation is being applied on ratoons as well as on plant cane is limited.

2.07 The efficiencies of the irrigation systems used may be improved. One third of the irrigated land is under surface irrigation, which might be converted to sprinkler, with a 40% increase in efficiency of water use but at higher costs, both in financial and energy terms.

2.08 The other two thirds of the irrigated land are under sprinklers. Drip irrigation can offer up to a further 40% increase in efficiency over sprinkler. It is in commercial use in Hawaii, and experiments with it are being carried out by the Mauritius Sugar Industry Research Institute (MSIRI) and at two sugar estates. It is relatively cheap to instal and operate. However management control will need to be at least as effective as with sprinkler. The change from sprinkler to drip systems will be slow, given firstly the necessary alterations to field-edge technology and secondly the present industry-wide investment in advanced sprinkler equipment.

2.09 Crop seasons were longer in the late 1970s than in earlier years. The higher the operating efficiencies of the factories (and the shorter the crop seasons), the greater the sucrose % cane and hence the lower the processing costs. There is little doubt that the extension of the seasons into bad weather conditions, due to problems of labour and of field mechanisation, has had materially adverse effects on profitability. In 1979 2 073 ha (2.6% of the area harvested) were treated with the cane ripener Polaris, with encouraging increases in sucrose % cane: MSIRI are experimenting with early maturing cane varieties so that sugar production at the beginning of the crop may be increased.

2.10 Since the area of land under cane is not capable of expansion, and petite saison cane planting is constrained, the principal sources of increased cane production would be improved irrigation efficiencies, destoning, and the introduction of early maturing cane varieties. This study puts forward a somewhat conservative estimate of the increase in production of sugarcane, based on the considerations already discussed, of 4% to 6.47 M t/y in 1990 as an average for the non-disaster years (para 7.20, Appendix 1). A return to the factory efficiencies of the early 1970s would provide enough capacity to process this extra cane.

2.11 Interline cropping has had very encouraging results (Section 1, Appendix 3). The principal crops are potatoes, maize and groundnuts; trials have been made with soyabeans, French beans, tomatoes and other vegetables. Mauritius has achieved self-sufficiency in potatoes in most recent years principally because it is an ideal interline crop. In 1979, 1 000 t of seed potatoes were imported; 8 300 t were produced and 1 200 t imported in what was a difficult year. They can be grown in each interline, usually in virgin cane. The Agricultural Marketing Board (AMB) provide storage facilities of 14 250 t, which are also used for onions and garlic.

2.12 Maize is a useful interline crop, particularly in view of its value as a constituent of animal feeds. It is usually grown in ratoons up to the third (after which the cane stools become too extended), but only in every other row (or alternatively two rows of maize between cane rows 7 feet (2.13 m) apart with a blank row of 3 feet (0.91 m), instead of the more usual rows 5 feet (1.52 m) apart - a method which has not been entirely successful). Optimum yields of maize in interlines are in a range of 1.8-2.4 t/ha, compared with 2.5-3.3 t/ha in normal field conditions 1/.

2.13 Total maize production in Mauritius in 1979 was 1 171 t, at an average of 2.5 t/ha (para 1.05, Appendix 3). This is used almost entirely in animal feed, but to date it is only a small proportion of imports. Maize imports in 1979 were

1/ IFAD, April 1980.

13 471 t. A maize dryer and mill have recently been installed at Benares in the south of the island in order to process crops grown by Savannah, Union and Britannia sugar estates. It processed 800 t in 1980/81, and has a storage capacity of 250 t.

2.14 Tomatoes have been grown interline in commercial quantities (8 400 t in 1979), and marketed as a fresh crop: it is unlikely that a processing operation would be commercially successful, principally because of the small scale of operation. Some groundnuts and French beans are also grown for domestic consumption.

Sugarcane processing

2.15 Most cane fields are harvested green. Some are burnt, and a small number, no more than 1% in 1979, are harvested mechanically. It is not likely that a material increase in mechanical harvesting can be made, given the topographic and physical conditions of the cane fields. A substantial amount (34% in 1979) of cane loading is mechanical (principally push-pile and grab), and there may be possibilities for further mechanisation of this operation.

2.16 There are 21 sugar factories in Mauritius. Two others went out of production in the late 1960s. The nominal capacities of the existing factories vary from 60 tc/hr (St Felix) to 240 tc/hr (F.U.E.L.). Mechanical time efficiencies are high, though they have fallen since 1971-75; overall time efficiencies are lower, mainly because of shortages of cane and increasing mechanisation of cane loading (para 1.03, Appendix 1).

Sugar production and marketing

2.17 The factories produced 646 000 t raw sugar in 1979 (the most recent non-disaster year), and 42 000 t refined. Three-quarters of the latter (28 000 t) went to the local market; all but 4 000 t of the raw sugar were exported. Total domestic sugar sales average 40 000 t (para 3.01 Appendix 10).

2.18 Millers receive 26% of the net proceeds of sugar and the planters 74%. The Government of Mauritius imposes a duty on export sales of sugar. This is on a sliding scale from zero for small planters to 13.5% for large planters and miller-planters. A recent budget surcharge has increased the latter rate to 23.625%. In 1979 the proceeds of the tax were Rs 281 M ($35.6 M) or 14% of the total revenue of The Mauritius Sugar Syndicate, which handles sugar industry commercialisation (Section 2, Appendix 10).

By-product production

2.19 Sugarcane tops Cane tops have a low sucrose content and are hence removed by the cane cutters and left in the fields with the trash. Where cane is burnt the volume of tops is reduced, and the trash is almost totally destroyed. Both on burnt and unburnt fields, however, tops (and trash) are considered to be useful sources of humus in the soil. The estimates of the amounts of cane discarded as tops vary from 13% to 19% (green) and from 16% to 26% (burnt) of the cane cut in the fields; an average figure of 17% is used, giving the 1972-79 non-disaster year average of 1.27 M t/y, and a projected 1990 average of 1.33 M t/y. All projected by-product figures are shown in para 7.20, Appendix 1.

2.20 Fly ash The powering of sugar factories by burning bagasse produces a fine ash in the boiler chimneys that is usually dispersed by the wind, though some remains in the chimneys.

2.21 Furnace ash The burning of bagasse (and occasionally wood) in the boilers of the sugar factories produces ash amounting to about 0.3% cane.

2.22 Filter mud Cane juice extracted in the sugar factories' milling tandems or diffusers is clarified using lime at temperatures of about 100°C. The mud is precipitated and extracted by a filter press. Currently filter mud is about 3.4% cane, giving 1972-79 non-disaster year production of 211 000 t/y, and an estimated 1990 production of 220 000 t/y.

2.23 Molasses Molasses is the highly viscous liquid remaining after the evaporation, crystallisation and centrifuging of sugar. It averages just over 3% cane by weight. Mean production was 191 000 t/y @ 86° brix in 1972-79 non-disaster years, and may be expected to rise to 199 000 t/y in 1990. The average sugar content in 1979 was 43%, which is low by world standards; however, there are large variations between the factories, reflecting differing factory efficiencies and maybe also varying characteristics of the cane varieties.

2.24 Bagasse When the mixed juice has been extracted from the cane, the remaining bagasse constitutes around 28% of the weight of the cane, giving production of 1 727 000 t in 1972-79 non-disaster years, and an estimate of 1 798 000 t in 1990.

2.25 Bagasse is used to fire boilers to produce the energy of the factories. Before it was generally appreciated that mineral oil was a wasting resource, the disposal of bagasse was an expensive and tedious operation. Most factories in Mauritius were designed to burn all their bagasse in oversized and expensive boilers. More recently, however, the value of bagasse as a source of energy has been realised and surpluses are now produced by all but the smallest factories. The present surplus is about 186 000 t/y and, if factory energy generation is optimised, this could rise to 500 000 t/y.

2.26 Vinasse (slops or stillage) Vinasse is a by-product of the distillation of alcohol from molasses. It contains 7-10% solids. As an effluent, it causes pollution; the solids contain about 9% protein, and a material amount of potassium. The Beau Plan distillery will produce 250 000 ℓ/d vinasse at full capacity; presently the yeast is removed and the remaining vinasse introduced into the irrigation water.

By-product utilisation

2.27 Livestock feeds Production of compound livestock feeds in 1979 was 28 600 t; imports of compound feeds and feed constituents were 54 300 t. The annual forage requirement is estimated to be 200 000 t of which up to half may be met by sugarcane tops (8% of total production of cane tops). Current utilisation and projected requirements of animal feeds are defined in Section 4, Appendix 5.

2.28 Apart from the use of cane tops as a forage, the only by-product of sugar manufacture to have been widely used for animal feed in Mauritius is molasses. It is estimated that an average of 2 500 t/y were so used during the period 1971-80, and that present use is about 6 000 t/y. The principal qualities of molasses as an animal feed are its high sugars content (giving good metabolisable energy, ME), and its viscosity which makes it useful as a binder or a thickener of feeds. It is used in the country's three feed mills and in mixtures with cane tops and other roughages whether fed fresh or ensiled. In the early 1970s, rations with high molasses contents were experimented with; these are still used to a limited extent, though in several feedlots rations with lower molasses contents are now being fed.

2.29 The crude protein in filter mud has been shown to possess a very low digestibility. At present this by-product is mainly returned to the fields as a fertiliser, though most independent planters do not collect their due shares from the sugar factories.

2.30 Untreated bagasse has a low nutrient value. Some methods of treatments to improve this have been investigated, but there is at present no commercial use of bagasse in animal feeds in Mauritius.

2.31 The crude protein content suggests that vinasse might be a possible animal feed, but removal of moisture is costly and energy-consuming. It is not used as an animal feed in Mauritius.

2.32 Alcohol Distilleries are operated by the sugar factories at Medine, Beau Plan and St Antoine. The one at Beau Plan is a modern 20 000 ℓ/d plant. The others are smaller and older, and it is possible that the one at St Antoine will close shortly. The distilleries mainly produce potable alcohol for the home market. Gilbeys (Mauritius) redistil alcohol bought from other distilleries. Some non-potable alcohol is sold locally. The total molasses offtake was about 15 000 t in 1979, and alcohol production was 3.2 M ℓ at 100°GL (End Table 9, Appendix 10). Medine makes vinegar for the local market and small quantities of alcohol are used for a variety of other purposes.

2.33 Energy Imports of mineral fuels cost Rs526 M in 1979 ($72 M) or 14% of total imports, and of this The Central Electricity Board (CEB) accounted for Rs67 M ($9.1 M).

2.34 In recent years the sugar factories have installed more sophisticated equipment such as back pressure and condensing turbines for converting steam into energy. The production of electricity by the factories is almost entirely limited to the sugar crop season, since present methods of baling and storing bagasse - a very bulky and awkward substance in relation to its energy content - are expensive and unsatisfactory. Surplus electricity is sold to CEB. Sales in 1980 were 27 GWh (End Table 4, Appendix 7A); present equipment will supply 47.8 GWh/y.

2.35 All of the island's distilleries are powered by steam produced by sugar factories. One tea factory, Bois Cheri, is fuelled by bagasse baled at and transported from Union St Aubin; the other tea factories are heated by oil fired boilers, which cannot readily be converted to bagasse. The same is true of most other industrial and agro-industrial users of steam.

2.36 Union are currently studying the production of methane from cane tops by anaerobic digestion.

2.37 Export Apart from the sugar itself, the only product of the industry which is exported in material quantities is molasses. Two companies have molasses terminals in Port Louis with a total capacity of 44 000 t (about one quarter of annual exports). In non-disaster years, after offtakes for animal feed and distillation, a total of 170 000 t (90%) is available for export. Export of molasses is described in Section 3, Appendix 10.

3. TECHNICAL OPTIONS AVAILABLE

3.01 Sugarcane, along with other giant tropical grasses, is one of the most efficient converters of solar energy to biomass. In this chapter the technical options available for utilisation of the major by-products of sugarcane are considered. With two exceptions, only options available when the crop is grown and processed in a conventional manner are examined. The exceptions are interline cropping and the 'Comfith' cane separator process.

Sugarcane production

3.02 Interline cropping Crops grown in interlines may be considered to be by-products of sugarcane production. They are discussed in Section 1, Appendix 3. Maize is most important for the livestock industry, which is also a potential major consumer of sugarcane by-products. However, increased production of maize now depends primarily on solution of the problems of mechanised harvesting and the establishment of drying plants and storage facilities. Plans are being made for a drying plant and mill at Medine (3 000 t/y) and for two additional plants at sites in the north and east of the island (1 500 t/y each).

3.03 The production of French beans, soyabeans and groundnuts should be further investigated as interline crops in view of their nitrogen-fixing characteristics, and also (in the case of groundnuts and soyabeans) because of the desirability of increasing production of vegetable oils for human consumption, and of oil cakes for inclusion in animal feeds, at the underutilised oil expresser plant at Mauritius Oil Processing Company Limited outside Port Louis.

3.04 Fodder cane The production of fodder cane for livestock feeding should be encouraged. The maximum quantity that could be produced would be of the order of 92 000 t/y based on the 1979 grande saison planting statistics.

Utilisation of sugarcane tops

3.05 Although some cane tops have always been used as a roughage feed, particularly in the past by smallholder cowkeepers, they are probably the most underutilised of all sugarcane by-products. Options for the use of cane tops are feeding as fresh material; ensiling fresh and/or wilted material for future feed use; and leaving in the field to dry followed by baling. Dried cane tops may be used as a low quality roughage feed, as a fuel, or as material for anaerobic digestion. Fresh cane tops may be used for the production of leaf protein.

3.06 Fresh and ensiled feed Methods of improving present collection and utilisation of cane tops as fresh or ensiled feed are discussed in paras 2.11-2.16, Appendix 5. Further investigation work is required into the possibilities of this option.

3.07 Dried cane tops Cane tops dried in the field can be collected in various ways to be stored and used as a low quality roughage feed or as a fuel. The most practical method of field collection is baling. The use of dried cane tops is not considered.

3.08 Leaf protein Limited investigations have been undertaken in Mauritius of the production of leaf protein from cane tops. As the economics of the process are marginal for high protein content forages (20-28% crude protein (CP)), they are even less favourable for cane tops with a CP content around 5%. In the Mauritian investigations one tonne of cane tops yielded four kg dry leaf protein (49.2% CP). It is not proposed that this option should be investigated further as the quantity of protein extracted has a feed value less than the cost of extraction (paras 2.38-2.40, Appendix 5).

Sugarcane separation (Comfith process)

3.09 A very small cane separation plant using the 'Comfith' process has in the past produced livestock feed in an investigation programme in Mauritius carried out by the Ministry of Agriculture and Natural Resources and the Environment's animal husbandry department; it is no longer so used. Although the process has been under development for over 15 years in Barbados and elsewhere, the available evidence suggests that it has yet to be proved to be technically or commercially viable (paras 2.01-2.04, Appendix 3). Consequently this option is not recommended for further consideration.

Utilisation of fly ash, furnace ash and filter mud

3.10 Fly ash has minor uses; for example it can be used in vacuum and other filters. MSIRI has already investigated this option. Furnace ash has a high potash content and is usually returned to the fields as a fertiliser.

3.11 Filter mud as a fertiliser It is likely that production of filter mud will increase with the mechanisation of cane loading operations. The present major use of filter mud in Mauritius is as a fertiliser.

3.12 Filter mud as a livestock feed Filter mud possesses a CP content of around 12% and high trace element contents. Its use as a livestock feed was investigated in Mauritius more than a decade ago and at that time it was decided that it was not a suitable feed on account of its low digestibility and other unfavourable factors (paras 2.17-2.26, Appendix 5). It is considered that this option should be further examined, specifically methods of wet feeding and the possibility that if dried it might substitute for imported trace element mineral supplements, particularly if economic methods of drying can be employed.

3.13 Wax from filter mud Although it is technically feasible to extract wax from filter mud, the process is not considered to be a viable option on account of market considerations (Chapter 4 and paras 2.02-2.03, Appendix 9).

Utilisation of molasses

3.14 There are a number of technical options for the use of molasses. One of the most interesting and controversial is whether a substantial part of the molasses that is at present exported should be used for the production of anhydrous ethanol; this would be blended at the rate of 20% ethanol/80% gasoline in order to provide a substitute fuel for imported gasoline.

Fermentation and distillation products

3.15 Options include ethanol as a fuel, potable alcohol and alcohol for other purposes, including chemicals that may be manufactured using alcohol as a base.

3.16 Ethanol as a fuel Technology for the production of anhydrous ethanol is well established and is detailed in Section 4, Appendix 6A, as are the options for the type of plant that may be required (Sections 5 and 6, Appendix 6A). Although ethanol itself may be used as a fuel in a hydrated form (95% ethanol:5% water), such use requires modifications of normal gasoline engine design. On the other hand anhydrous ethanol (99.6 w/w ethanol) may be blended at the optimum rate of 20% with gasoline to produce a fuel that only requires retuning of gasoline engines. Indeed, this blend improves the octane rating of regular grade gasoline to that of premium grade, and anti-knock additives are not required. The possibility of using ethanol as a substitute for diesel fuel and kerosene has also been examined (paras 1.05-1.07, Appendix 6A), but it is considered that such substitutions would not be practical. The fusel oil fraction of the distillation process can be added to the ethanol/gasoline blend, together with a denaturant.

3.17 The use of a 20% ethanol/80% gasoline blended fuel in Mauritius has been studied by the oil importing companies (paras 2.09-2.10, Appendix 6A): they conclude that its use would be technically feasible, subject to further tests in January 1982.

3.18 It is estimated (paras 3.01-3.02, Appendix 6A) from gasoline consumption data and projections that the requirement for ethanol would be of the order of 11-12 M ℓ/y by 1990, so that a 15 M ℓ/y plant should be of sufficient capacity to allow for variations in demand. The major options for ethanol production of this order are:

a) a 107 000 ℓ/day plant operating only through the sugar crop season;

b) a 50 000 ℓ/day plant operating throughout the year; and

c) an extension to the Beau Plan potable alcohol distillery to produce 50 000 ℓ/day.

3.19 A major problem of any distillation plant is the disposal of vinasse. There are four major methods of disposal:

a) direct disposal on the land;

b) evaporation to 60% solids for use as an animal feed or fertiliser;

c) evaporation and incineration in the plant boilers; and

d) anaerobic digestion to produce biogas.

Direct disposal appears the least costly method but is only satisfactory if the vinasse can be diluted sufficiently in irrigation water. Anaerobic digestion of vinasse is attractive in energy terms.

3.20 Potable alcohol The only option for consideration is for improvements in the performance of the older distilleries at Medine and St Antoine (para 2.08, Appendix 6B).

3.21 Alcohol used for other purposes A small quantity of distilled ethanol is used as denatured spirit for general industrial use in Mauritius and for vinegar and perfume manufacture (End Table 9, Appendix 10).

Other fermentation products

3.22 Options considered in Appendix 6B are baker's yeast, fodder yeast, vinegar/acetic acid, citric acid, monosodium glutamate, and the use of ethanol as a feed stock for the manufacture of ethylene and its derivatives. There are other fermentation products that can be produced from molasses, such as butanol-acetone, lactic acid, glycerol and itaconic acid, but these are not remotely viable options in Mauritius and are not considered.

3.23 Baker's yeast Before fermentation, molasses is clarified and sterilised. Fermentation using strains of Saccharomyces cerevisiae is normally a batch process, air being blown into the fermenting vessels to provide aerobic conditions for yeast growth. A 800 t/y plant for the manufacture of baker's yeast was opened at Beau Champ sugar factory in 1975 and closed in 1978. The operation was initially run with technical partners from South Africa; however the quality of the product was indifferent and the locally made cans unreliable. With a Canadian firm replacing the South Africans in 1978, the quality of the product reached a high standard, but the company was by then bankrupt. The principal reasons were higher than expected costs and price cutting by stronger competitors in the chosen export markets (paras 3.01-3.06, Appendix 6B).

3.24 Fodder yeast Fodder yeast is produced by aerobic fermentation of molasses using a process similar to that used for the production of baker's yeast. It has a protein content of 50%. Some of the most suitable yeast species to use are Torulopsis utilis, Candida arborea and Candida utilis. Production methods are described in paras 4.01-4.04, Appendix 6B, and costs and feed value are considered in paras 2.32-2.34, Appendix 5.

3.25 Vinegar/acetic acid The production of up to 100 000 l/y of vinegar in Mauritius is essentially a small scale operation that satisfies local demand. Molasses is diluted and nutrients added prior to fermentation in wooden vessels (paras 5.01-5.02, Appendix 6B). Acetic acid is not distilled from vinegar in Mauritius.

3.26 Citric acid This is produced from the fermentation of clarified, sterilised and diluted molasses using strains of the fungus Aspergillus niger that are only obtainable from existing manufacturers who do not release cultures to competitors; citric acid manufacture is therefore not considered to be a viable option (paras 6.01-6.02, Appendix 6B).

3.27 Monosodium glutamate It is manufactured by the anaerobic fermentation of molasses using strains of Micrococcus glutamicus under slightly alkaline conditions in the presence of urea. Purification of the product is a complex process (paras 7.01-7.02, Appendix 6B).

3.28 Chemicals derived from ethylene Many chemicals may be produced from ethylene using ethanol as a feedstock. The size of plant required would be very large in relation to the quantity of molasses that would be available in Mauritius for ethanol production, so that this option is not considered (paras 8.01-8.07, Appendix 6B).

As a livestock feed

3.29 Molasses can be fed to cattle at a high level (up to 6 kg/head/d) together with urea, minerals and protein and carbohydrate concentrates. This is the option that has been pursued in Mauritius during the last decade with varied results. At a middle level of intake (above 15-18% of the ration) molasses appears to lower the digestibility of the fibre content of roughage and this option is not advocated. The use of molasses as a constituent of animal feeds is described in paras 2.01-2.06, Appendix 5.

3.30 At a lower level of intake, molasses can be fed as a liquid mixed with urea and minerals; in block form; absorbed into the pith fraction of bagasse; or by adding molasses to a complete ration or to the roughage fraction of the ration such as cane tops. This option requires further investigation.

3.31 In the past it was considered that poultry and pigs could not be fed large inputs of molasses, but more recent investigations suggest that molasses could constitute 20% and 30% of the rations of poultry and pigs respectively. This option should be tested on a pilot scale.

er uses

Molasses can be used as a feedstock for the manufacture of chemicals other than those obtained by fermentation, such as dextran and aconitic acid. These options have not been considered.

Utilisation of bagasse

3.33 Present technical options for the use of bagasse are more numerous than past utilisation would suggest. The principal one is as a source of energy; less important ones are as raw material for fibre products, chemicals and livestock feeds, as well as for animal (chiefly poultry) litter or as a fertiliser.

<u>As a source of energy</u>

3.34 Bagasse can be used to produce energy in the form of steam and/or electricity, charcoal, producer gas and biogas.

3.35 <u>Steam and/or electricity</u> If the efficiency of the factory process sections in terms of demand for steam were improved, less bagasse would be needed for internal factory fuel and additional electricity could be produced from the surplus bagasse and sold to CEB.

3.36 The 21 sugar factories can be classified into three groups according to their energy balances (paras 5.01-5.04, Appendix 7A). These are:

Group I: Six small factories (total capacity 460 tc/hr) with little scope for development of energy production.

Group II: Six medium size factories (total capacity 660 tc/hr) with simple process sections.

Group III: Nine larger factories (total capacity 1 210 tc/hr) with rather more economical process sections.

Group II and III factories could be developed to Groups IV to VI (paras 5.05-5.07, Appendix 7A) by improving the process sections, and by installing higher pressure boilers.

3.37 If it is assumed that bagasse can be stored between crops (see paras 3.40-3.42 below), then electricity production at Group II and III factories could be maximised in three steps. These are:

Step I: Upgrade the process sections of Group II and III factories to use energy in the most economical manner (now as Group IV factories, operating at 31 bar A at 350°, Section 5, Appendix 7A). This action would produce 9.7 Gwh/y from back pressure turbo-alternators and 344 000 t/y of surplus bagasse.

Step II: Instal 'woodex' pelleting equipment (paras 7.05-06, Appendix 7A) at all the new Group IV factories to provide 277 000 t/y of bagasse pellets.

Step III: There would be three technical options as to how the bagasse pellets could be used to produce electricity. These are:

Option A CEB would instal the proposed 30 MW coal fired power station at Port Louis equipped to burn bagasse pellets as an alternative fuel. Total electricity produced from bagasse would be 229 GWh/y, providing an average of 30 MW during a 320 day operating year (para 8.12, Appendix 7A).

Option B Instal 10 MW power stations at three of the the larger existing factories. These would become Group VI factories (para 5.07, Appendix 7A) equipped with boilers operating at 46 bar A at 440°C. The total electricity produced from the bagasse would be 201 GWh/y, at an average of 26 MW during a 320 day operating year (para 8.14, Appendix 7A).

Option C Use the existing 31 bar A at 400°C boilers (Group V factories: para 5.06, Appendix 7A) and the new 10 MW condensing turbo-alternator at Medine, with two additional 10 MW turbo-alternators at other factories already partly upgraded to Group V (or the 20 MW turbo-alternator currently under investigation for F.U.E.L.). The total electricity produced from bagasse would then be 182 GWh/y at an average of 24 MW during a 320 day operating year. The capital cost of this option would be much smaller than those of Options A or B (paras 8.16-8.20, Appendix 7A).

3.38 An additional option would be to equip all Group II and III factories with boilers operating at 46 bar A at 440°C (ie upgrading them up to Group VI status -para 5.07, Appendix 7A). However, this would entail a massive investment and as a consequence the option has not been considered.

3.39 A further option is to maximise the production of electricity by the sugar factories during the crop season only; it would no longer be essential to store bagasse. The option has not been costed because it is unattractive to the factories. Total electricity that could be produced would be only 166 GWh/y; the only saving would be the cost of the fuel oil that would otherwise be burnt in CEB's diesel generators.

3.40 Pelleting of bagasse   Condensing turbo-alternators are designed for continuous operation and are therefore most suitable for producting electricity for the base load. This means that they would have to be operated on Sundays and during the out-of-crop season, and hence that the bagasse required for generating steam for their operation would have to be stored. The storage of bagasse has always presented problems. Pelleting bagasse would be one solution. Savannah experimented in the past with two SPM duplex presses, with a combined theoretical output of 2.5 t/h of logs containing 12-14% moisture. Unfortunately only 10% of working capacity was attained, and the effort was abandoned and the machinery sold.

3.41 A new bagasse pelleting process known as 'Woodex' is currently in its first year of production in Hawaii. It is based on a method developed for pelleting wood chips and it at present being investigated for possible use in Mauritius. Bagasse is dried utilising energy available in the boiler flue gases and then compressed into solid fuel pellets that have a density of 1 410 kg/m^3 and a net calorific value of 16 200 kJ/kg (cf coal 32 564 kJ/kg). The plant operating in Hawaii has a capacity of 70 t/h of bagasse; it is expected to produce 20 000 t pellets from 112 000 t bagasse. It is currently working around 50% of capacity. The pellets can be handled and stored easily and could be transported during the out-of-crop season by the raw sugar trucks. A further advantage of using pellets is that because the bagasse is dried by the heat in the flue gases, there should be a net gain in the energy efficiency of the whole system. It has however not been established in Mauritius that the temperatures of the flue gases are high enough at all factories to provide the energy source of the process (para 7.06, Appendix 7A).

3.42 Pelleting and storing surplus bagasse not only makes it possible to generate electricity all the year round, but also allows for flexibility in location of the generation site, making possible the technical options described in para 3.37 above.

3.43 Charcoal   Charcoal can be produced from bagasse but no industrial scale plants are operating at present (Section 1, Appendix 7B). Two major types of carbonising plant are considered suitable for producing charcoal from bagasse. These are:

a) the continuous horizontal retort (a plant of this type is operating in Kenya producing charcoal from coffee hulls); and

b) The vertical kiln (this is the type that is under consideration by Doger de Speville and Company, a subsidiary of Rogers and Company, Port Louis).

In both types of plant it will be necessary to pre-dry the bagasse to a suitable moisture content using flue gases and/or heat produced by the combustion of gases generated by the carbonisation process. As the bagasse would probably have to be dried to a moisture content as low as 10% a substantial drying plant would be required. The charcoal also has to be extruded, briquetted or pelleted using molasses as a binder, before it can be used (paras 1.11-1.13, Appendix 7B).

3.44 Producer gas Plants using bagasse as a fuel to make producer gas have been built; however, they are not a very attractive option as they lack flexibility and require a prolonged start-up period (Section 3, Appendix 7B). The pyrolysis gases, a by-product of charcoal production, could be used for the same purposes as producer gas; it is possible to operate charcoal plants to produce different proportions of charcoal and gases. For example, in a typical vertical plant the yield of charcoal can be varied between 10 and 35% depending on the air supply. MSIRI plan to investigate this option.

3.45 Biogas Bagasse can be used to produce biogas; however, it is not an attractive option as more than 50% of the raw bagasse would not be biodegradable by methogenic bacteria without expensive pre-treatment (Section 2, Appendix 7B). Small quantities of bagasse could be mixed with animal manure to provide raw material for a biogas generator at feedlot sites.

As a source of fibre

3.46 As a source of fibre, raw bagasse can be used to manufacture pulp and paper, particle board, fibreboard, medium density fibreboard and cement bonded particle board.

3.47 Pulp and paper About four tonnes of 50% moisture content bagasse produce one tonne of pulp. It is usual to mix bagasse pulp with wood pulp in paper making. The proportions of the two components vary considerably according to the paper quality required; on average three parts of bagasse are mixed with two of wood pulp.

3.48 Feasibility studies have been made of a paper mill in Mauritius with a capacity of 125 000 t/y. In present circumstances there would be insufficient surplus bagasse available for a mill of this size and some method of replacing bagasse at present used as fuel would be necessary. It has been proposed to provide new oil-fired boilers to a number of small sugar factories, and purchase all their bagasse. It is not considered that this is an attractive option (para 2.21, Appendix 8). There are technical difficulties such as the provision of an adequate water supply and efficient effluent disposal; the market aspect is unattractive; and the process is a net consumer rather than a producer of energy.

3.49 Smaller scale paper mills have much the same disadvantages as the large mill, and in addition they have higher production costs (paras 2.22-2.30, Appendix 8). Thus a small mill is not an attractive option.

3.50 Particle board This is produced by depithing bagasse and bonding the fibres under pressure with the inclusion of resin and other chemicals. This option has been attempted in Mauritius. A 3 750 t/y capacity plant (the smallest available) operated from 1971 to 1978. It failed for various reasons (Section 3, Appendix 8). The company was put in voluntary liquidation. The machinery is still on site and is in reasonable condition; the liquidators are presently making efforts to resume production.

3.51 Fibreboard There are two types of fibreboard, compressed (hardboard) and non-compresssed (insulation board). Bagasse is cooked with lime, caustic soda or neutral sodium sulphite and mechanically reduced to a pulp. The boards are made by wet-forming and pressing. This option has not been attempted in Mauritius and is not recommended (paras 4.01-4.11, Appendix 8) because the particle board factory could supply the country's need for boards at a much lower cost.

3.52 Medium density fibreboard (MDF) This is another option which has not been tried in Mauritius. The board is formed by a dry process similar to that used in the manufacture of particle board (paras 4.12-4.14, Appendix 8). The option is not considered for the same reason that fibreboard manufacture is not recommended.

3.53 Cement bonded board This type of board is made in a similar way to normal particle board, but using cement as a binder instead of synthetic resin. The process has not been used in Mauritius (paras 4.15-4.16, Appendix 8) and is not recommended as an option. There are technical problems arising from the antipathy of sugar and cement, and it is unlikely that a commercially viable process could be developed.

As a source of chemicals

3.54 Bagasse can be used as the raw material base for the manufacture of a number of useful chemicals. Of these only furfural is considered in this report.

3.55 Furfural The raw material for furfural must be available in large quantities and possess an average pentosan content of 26%. Bagasse yields 8-10% furfural on a DM basis: it is recovered by hydrolysis with steam at high pressure and temperature. The resulting hydrolysate is distilled (Section 1, Appendix 9).

As a source of livestock feed

3.56 Raw bagasse possesses a very low nutritive value even for ruminant livestock. It is unlikely that the option of using bagasse as a feed will be taken up on any scale until methods of upgrading the nutritive value can be shown to be economically worthwhile. Alternative methods of upgrading nutritive value are:

a) treatment with caustic soda this includes three different techniques:

  i) high volume dilute solutions for soaking the bagasse; this is not a very suitable method for large scale operation;
  ii) low volume concentrated solution or solid caustic soda; a method more suited to large scale operations; and
  iii) the addition of caustic soda followed by ensiling.

b) treatment with ammonia in liquid or gaseous form the bagasse is placed in an airtight container and treated with ammonia;

c) treatment by steaming at a high temperature and pressure; and

d) ensiling with urea this is a variation on the use of ammonia; when urea is added to the silage it is hydrolysed to ammonia.

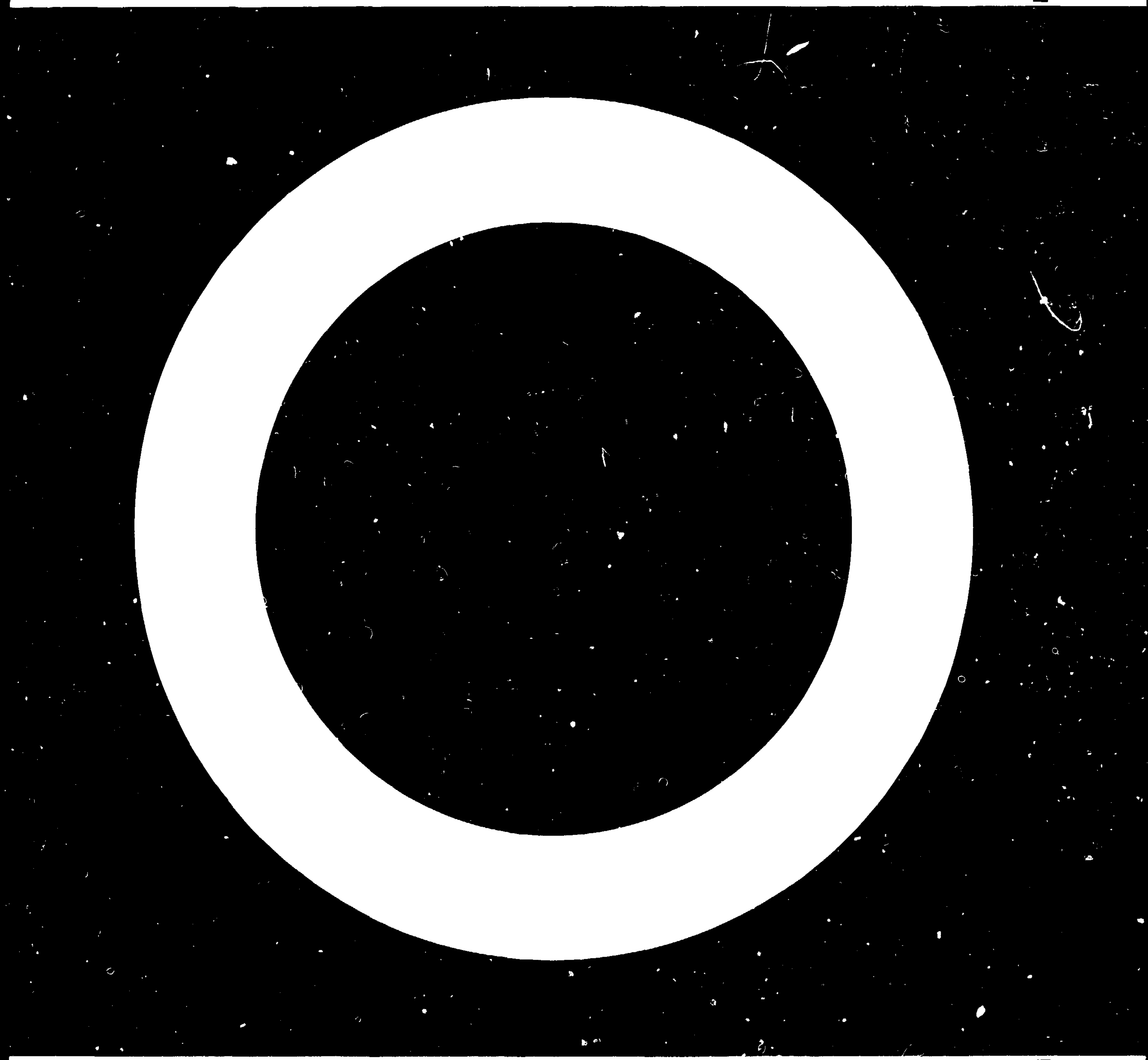
3.57 Past attempts in Mauritius to improve the nutritive value of raw bagasse have not been followed through to the pilot or commercial stage; it is considered that all treatment methods should be re-examined and pilot investigation work started if a method were considered to be economically worthwhile (Section 3, Appendix 5).

Other uses

3.58 Other options are the use of bagasse for deep litter in poultry houses and as an organic fertiliser; both have been adopted in Mauritius on a small scale.

Extraction of protein from sugarcane juice

3.59 Sugarcane juice contains up to 0.12% CP that can be extracted at an appropriate stage in factory processing. In the past MSIRI has investigated the possibility of extraction. As a number of new methods are now available for the removal of protein from liquids and some part of the cost of removal could be included in the cost of sugar factory processing, it is suggested that protein extraction from sugarcane juice would be a more promising process than extraction of leaf protein from cane tops (para 7.08, Appendix 5) and that this option should be further investigated.



4. MARKET ANALYSIS

Sugar

4.01 All sales of sugar in Mauritius on both the domestic and export markets are undertaken by The Mauritius Sugar Syndicate. The local market averages 40 000 t/y for both domestic and industrial consumption, the major part comprising white sugar. Prices are fixed by Government and, in spite of price increases over recent years, are below the cost of production of sugar.

4.02 Sugar exports reached a record level of 686 000 t in 1973/74, since when they have fluctuated between 620 000 and 660 000 t/y. Exceptions have been in years when cyclones damaged the crops as in 1975/76 and in 1980/81; in these years exports fell to around 440 000 t. The majority of exports are in the form of raw sugar at 98.5° polarisation, although small quantities of white and demerara sugar are sold to the EEC.

4.03 The EEC is the major market for exported sugar, the bulk of trade going to the UK. Mauritius has a quota equivalent to about 507 000 t tel quel (shipped weight) in the EEC market under the ACP Protocol on sugar annexed to the Lomé Convention. The price of raw sugar delivered under this quota is fixed annually and in 1980/81 was ECU 35.98/100 kg at 96° polarisation cif European port (equivalent to £222.04/t ($431.53) for sales to UK).

4.04 The balance of exports are sold on the world market. This market is managed under the International Sugar Agreement (ISA) to which Mauritius is a signatory. The most important destination is the United States where Mauritius benefits from duty free access under the US Generalised System of Preferences. Small quantities are also normally sold to Canada. Prices in both these markets are based on world prices.

4.05 Due to a poor crop in 1980/81, no sales were made to the world market in that year. For 1981/82 the sugar crop is estimated at a maximum of 600 000 t. Besides the 507 000 t quota, Mauritius will also be shipping 47 000 t to the EEC under the "force majeure" provisions of the Protocol to make up for shortfalls in delivery in 1980/81. With local consumption averaging 40 000 t/y and a likely stock-holding obligation of 10 000 t under the provisions of the ISA, the 1981/82 crop is already accounted for. Thus for the second year running Mauritius is unlikely to export sugar on the world market.

4.06 In a normal year Mauritius could expect to sell about 550 000 t to the EEC and on the local market, the remainder of the crop being sold on the world market. So far, Mauritius has always sold all its sugar production and it is safe to assume that this will continue in the future. In an economic analysis the price used would be that obtained at the margin for sugar sales, ie the world market price.

4.07 Sugar prices on the world market have fluctuated widely in the past and can be expected to continue to do so. 1980 was a period of relatively high prices, the ISA daily price rising to over 40¢(US)/lb (88¢/kg) in October. Subsequently, increases in production have led to a sugar surplus in 1981 and prices had fallen to 16¢/lb (35¢/kg) by July 1981. For the purposes of this report a long-run average price of 20¢/lb (44¢/kg) fob and stowed Caribbean port has been assumed. Since freight rates from the Caribbean to the USA and from Port Louis to the ports of major world market importers of Mauritius sugar are unlikely to be materially different in relation to the values of the cargoes, this price may be taken as equivalent to the fob Port Louis price (paras 2.14-2.15, Appendix 10).

Molasses

4.08 The marketing of molasses in Mauritius is carried out by two companies - Mauritius Molasses Company Limited (MM) who are responsible for about 55% of sales and Alcohol and ...ses Company Limited (A&M).

4.09 ...ter supplying the domestic market (15 000 t/y to the distilleries and 6 000 t/y for animal feed) the balance is exported, principally to the UK. Total quantities exported over the last three years have been:

1978/79	186 000 t
1979/80	187 000 t
1980/81	150 000 t

MM sell under a long term contract with United Molasses Company Limited, the price under this contract being based on a formula applied to selling prices in the UK, USA and continental Europe. The final price paid to millers and planters is arrived at by deducting export duty and costs from the fob price. In contrast A&M sell only two cargoes under long-term contracts, the remainder being sold by tender. The price they receive is therefore different to that received by MM but, taking one season with another, prices average out at much the same level.

4.10 Although a by-product, the status of molasses on the world market has risen in recent years. Its major use is in animal feeds. Between 1970 and 1980 European demand more than doubled. This reflects the rapid development of the compound feed industry over the decade and the fact that EEC policies have kept cereal prices high, encouraging the use of other ingredients such as molasses in feeds.

4.11 Over this same period, however, consumption in the USA nearly halved. Here lower grain prices made molasses less competitive as a component of animal feeds, especially in the late 1970s when molasses prices fell sharply. The market for molasses in the Far East has remained relatively static, the main use in this region being for industrial fermentation and distillation.

4.12 Molasses prices have always been subject to wide variations, and in such a volatile market future prospects are hard to predict. Demand will depend primarily on the growth of the EEC animal feed market and price relationships within that market. New markets may also affect demand, especially if many of the gasohol projects currently being proposed in various countries are implemented. As far as fob prices are concerned, ocean freight rates are also likely to play a large part.

4.13 Following discussions with the trade, an fob price of $75/t (Rs769) has been used for future sales of molasses from Mauritius. In view of the uncertainty of this figure, a low forecast of $65/t (Rs666) and a high forecast of $85/t (Rs871) are proposed for sensitivity analyses.

4.14 For the financial analyses in this report, ex-factory prices were derived by deducting export duty and the costs of exporting from these fob prices. Thus an ex-factory price of Rs567/t 86° brix ($54) is arrived at. To this price a transport cost of Rs33/t is added, giving a price of Rs600/t ($59) at a distillery in Mauritius. The corresponding low and high prices are Rs509 and 690/t ($50 and $67) (paras 3.12-3.14, Appendix 10).

Ethanol from molasses

4.15 Present ethanol market. The utilisation of ethanol in Mauritius in 1979 was as follows (End Table 9, Appendix 10):

	£'000 100% GL
Rum	2 473
Refined spirits	283
Denatured spirits (heating and lighting)	115
Power alcohol	211
Vinegar	9
Perfumes and drugs	92
Export	20
Total	3 202

The major use for ethanol is thus the production of alcoholic drinks. Three companies supply the potable alcohol market - New Goodwill Limited (NG), Mauritius OK Distillery Limited (OK, a subsidiary of Harel Freres) and Gilbeys (Mauritius) Limited. Of these NG and OK only dilute and bottle the alcohol, while Gilbeys redistil it to produce a range of cane and other spirits. Only NG, who hold 90% of the market, are allowed to market their product as "rum" (paras 5.01-5.04, Appendix 10).

4.16 Both the statistical evidence and discussions with distillers and bottlers confirm that the use of ethanol for alcoholic drinks has remained relatively static over recent years. In 1979 the potable alcohol market was 6.1 M ℓ at 40° GL, ie 6.7 ℓ/head, which is a relatively high level of consumption. In view of the present economic difficulties, the potential for growth in this market is limited and, at best, only likely to follow adult population growth. Considerable excess capacity exists in both the distilleries and the bottling plants; capacity is therefore not a constraint to growth.

4.17 Besides the local market, Gilbeys have also tried to find export markets for their white rum, brand name Green Island. This has so far proved unsuccessful. The export market for rum is described in paras 5.10-5.21, Appendix 10.

4.18 The major importers of rum in the EEC are the UK, West Germany and France, although the French market is effectively closed to new supplies. Other countries importing significant quantities are the USA, Australia, New Zealand and Japan.

4.19 The prospects for Mauritius to sell rum in any of these markets appear to be very limited. This would be especially so in the white rum market, primarily due to the present dominance of Bacardi and the very high promotional budget required to launch a new brand. Darker rum markets are normally highly developed, with long established competition between a few brands. At present surplus capacity exists in the traditional rum supply countries. In this sector of the market the best prospects would seem to be in the USA, New Zealand and Japan, though these are still extremely competitive markets and therefore difficult to break into.

4.20 Besides the potable alcohol market, ethanol has a number of other uses in Mauritius. It is denatured for heating and lighting purposes and to produce power alcohol. Small quantities are used in the manufacture of a range of products including perfumes and cosmetics, medicines and drugs, and vinegar. Production of these is geared to meet local demand and fluctuates around low levels. This production can be expected to continue in the future (paras 5.05-5.07, Appendix 10).

4.21 Exports of ethanol have been on an irregular basis involving only small quantities. This is to be expected since ethanol is not a widely traded commodity and is easy to produce. Thus even if markets are found they cannot be regarded as reliable in the long term.

4.22 Ethanol as a fuel The potential market for ethanol as a 20%/80% blend with gasoline is a function of gasoline consumption (Section 1, Appendix 6A).

4.23 Gasoline consumption in Mauritius more than doubled from 1971 to reach a peak of 67.2 M ℓ in 1978. By 1980, however, consumption had fallen back to 53.5 M ℓ. This drop reflects the general stagnation in economic growth with the consequent reduction in consumer spending power. In particular the rapid rise in gasoline prices, which trebled between January 1979 and July 1981, have had a major impact on consumption.

4.24 Forecasts for gasoline consumption show a continued decline in 1981, followed by a levelling off in sales anticipated at 47.8 M ℓ in 1983. These predictions reflect the deepening of the current recession and the expected slow recovery in economic growth. Furthermore, new vehicle registrations will continue to fall with the imposition of import quotas, the current high level of import duties (over 200%), and the further devaluation of the Mauritius rupee. This in turn can be expected to cause a reduction in the total number of motor vehicles registered, and at the same time there is likely to be an increase in fuel efficiency.

4.25 The position after 1983 will depend primarily on the general economic situation, the level of gasoline prices, and policy measures adopted towards motor vehicle imports. On average a growth rate in gasoline consumption of 2-3%/y has been assumed, resulting in demand expanding to between 55 and 60 M ℓ by 1990. Using a 20% blend of ethanol in gasoline, between 11 and 12 M ℓ of ethanol would be required (para 1.13, Appendix 6A).

Other fermentation and distillation products

4.26 The baker's yeast plant closed in 1978 because the market for baker's yeast in Mauritius is very small, and the intention was to develop export markets, initially in Indonesia and Sri Lanka. The international yeast market is highly competitive and dominated by a few large companies. One company in particular was able to reduce the price of their baker's yeast sold to Indonesia, forcing the Mauritian company to sell yeast at below the cost of production. The combination of a small domestic market and difficulties in establishing a long term export market suggest that further investment in baker's yeast production is unjustified (Section 3, Appendix 6B).

4.27 Fodder yeast The protein content of 50% is approximately equivalent to that of soyabean meal. Over 5 000 t of oilseed meal were imported into Mauritius in 1980 and fodder yeast could substitute for a significant proportion of this. However, in view of the high cost of production in comparison with oilseed meal prices, it is unlikely to prove a viable option (Section 4, Appendix 6B).

4.28 Citric acid This is produced and marketed by three or four companies worldwide. Without the collaboration of these companies, and in view of the small local market, citric acid production is not considered viable in Mauritius (Section 6, Appendix 6B).

4.29 Monosodium glutamate There is considerable excess world production capacity. With limited domestic market opportunities, it is difficult for any new producer to enter the world market (Section 7, Appendix 6B), and production in Mauritius is not considered further.

4.30 Ethylene and its derivatives have domestic markets which are far too small for consideration to be given to the establishment of economic production facilities (Section 8, Appendix 6B).

Electricity from bagasse

4.31 CEB controls the production and distribution of electricity in Mauritius. The total units generated from all sources over the last two years are as follows:

GWh	1979	1980
Hydro power	59	33
Thermal power	270	24[illegible]
Sugar factories	26	27
Total	355	[illegible]

In 1979 the sugar factories produced 7% of the total units sold by CEB. This figure has recently increased with the commissioning by Medine of a [illegible]0 MW condensing turbine which is expected to produce an additional 2[illegible] GWh/y.

4.32 Projections of future demand for electricity in Mauritius were made to the year 2000. Following discussions with CEB, for whom other consultants have made projections of electricity production and demand, it was agreed that an average growth rate of 4%/y should be used to project future electricity production. Thus the total units required to be generated to the year 2000 are as follows:

	GWh
1980	355
1985	432
1990	525
1995	639
2000	778

4.33 The shape of the daily demand curve is also important in assessing the potential for using bagasse for electricity generation. Present daily demand can be divided into three categories:

i) The base load which averages about 25 MW throughout the day.

ii) The day load extending from 08.00 to 22.00 hr when demand averages around 50 MW (an increase of 25 MW over the base load).

iii) Two peak periods: one in the morning at 11.00 hr and a more important one at 20.00 hr. The maximum demand in 1980 was 83 MW (33 MW above the day load).

4.34 In projecting future demand for electricity it has been assumed that the shape of the daily demand curve will remain constant. Thus, at a growth rate of 4%/y, by 19[illegible] the loads will be as follows:

Base load	55 MW
Day load	110 MW
Peak load	182 MW

4.35 The options of using bagasse and other energy sources to generate electricity to meet these demands, as well as the possibilities for using bagasse to generate electricity during the out-of-crop period are discussed in Chapter 3 and Appendix 7A.

Pulp and paper

4.36 Since only 3 500 t of newsprint and paper were imported into Mauritius in 1979 (the peak year), virtually all the production of the proposed 125 000 t/y paper mill will need to be exported. So far the two countries that have built bagasse newsprint mills, Mexico and Peru, have done so in order to substitute for imports: there is no evidence of any substantial world trade in bagasse paper or pulp (paras 2.15-2.16, Appendix 8).

4.37 On a world basis there is expected to be considerable excess newsprint production capacity in the mid-1980s. For newsprint produced in Mauritius it has been suggested that likely markets are East Africa and India. Export prospects to Africa are very doubtful; in 1979 the whole continent (excluding South Africa) imported only 91 000 t, and several countries are reported to be building wood pulp mills (paras 2.17-2.18, Appendix 8).

4.38 India is a more difficult market to assess. In 1980 domestic production capacity was 55 000 t and imports amounted to 312 000 t. A newsprint mill with a capacity of 75 000 t is due to start production in 1981, but even so the import market could absorb Mauritian production. Mauritius would need to capture a large share of the Indian market, whilst trade preference appears to be against reliance on a single supplier. However, Indian consumption appears to be subject to wide fluctuations and the market is probably not a reliable one. India also has a large sugar industry; in September 1981 IBRD announced financial support for a $237 M (Rs2 430 M) 100 000 t/y paper mill using bagasse in Tamil Nadu State. Thus the Indian market must be regarded as uncertain (paras 2.19-2.20, Appendix 8).

Particle board

4.39 The particle board factory established in 1971 manufactured on average 750 t of boards per annum, in thicknesses of 4-30 mm, until it was closed in 1978. These boards were sold on the local market in competition with imported plywood. The main use was in office partitioning and furniture. Due to high freight costs the boards were not competitive on export markets.

4.40 A market study undertaken in 1970 concluded that there was a total market in Mauritius for 1 200 t/y of boards. By 1979 this market was estimated to have risen to 3 500 t/y. Using import figures for plywood, and assuming this to be of 4 mm thickness, total markets of 1 200 t/y in 1970 and 3 700 t/y in 1978 are obtained. Since plywood is imported in a range of thicknesses from 3 mm to 18 mm these figures must be regarded as conservative estimates of the market size. Even so, with the factory having a capacity of 3 750 t/y, in order to operate anywhere near full capacity it would need to supply a high proportion of the current plywood market. The fact that the prices of imported plywood are now relatively much higher than they were in the early 1970s may be of some assistance.

4.41 Particle board only achieved a low penetration in the domestic market. A number of marketing aspects were associated with this. In particular, there was a lack of sales promotion in teaching customers how to handle and use the boards.

4.42 In view of the small size of the local market in relation to the factory's capacity, it will be difficult to re-open the factory profitably to supply this market alone. The most satisfactory way to restart production would be on the basis of a long-term contract which would at least ensure that a break-even point is reached. At the time of the team's visit to Mauritius the possibility of a 3 000 t y contract with a South African company was being investigated. The particle board factory is described and technical recommendations are made in Section 3, Appendix 8.

Charcoal

4.43 Proposals are currently being put forward in Mauritius to study the technical possibilities of making charcoal from bagasse. According to FAO, in 1979 nearly 16 M t of charcoal were produced worldwide of which only 2% entered international trade, production being predominantly for domestic utilisation. The reason for this is that charcoal is a bulky, low value commodity, with packing and freight charges accounting for a high proportion of the final price. Trade that does take place tends to be concentrated on a regional basis.

4.44 The main uses of charcoal are industrially for metal smelting and domestically as a cooking fuel. The stated intention in Mauritius is to use a pilot plant to agglomerate charcoal for sale in the domestic market in the shape of sticks. Present demand is low, and the product would therefore be sold as a substitute for other cooking fuels. Any further production would be made, at higher cost, into briquettes. This would mean selling to the high value barbecue markets, with France and Germany probably offering the best prospects. Little information is available on the Middle Eastern markets; these would be worth investigating in view of their proximity, size, and their lack of alternative solid fuels.

4.45 It is important that market studies be carried out in conjunction with technical investigations on making charcoal from bagasse. In particular, it will be necessary to establish that bagasse charcoal has the necessary physical properties to compete in these markets and, in view of the high freight cost, that it can be produced and marketed at a competitive price. The market prospects for charcoal manufacture in Mauritius are described in paras 1.14-1.20, Appendix 7B.

Furfural

4.46 This is primarily used as a feedstock for the production of furfuryl alcohol, an intermediate chemical in the manufacture of foundry resins. It is extracted from agro-industrial residues of which bagasse is one. The major markets are in the industrialised countries, where demand has been growing in recent years. However, local demand in Mauritius is negligible and the prospects for exporting furfural are not promising. Over 90% of the world's supply is controlled by one company, which is able to create unfavourable trading conditions for new suppliers. The market in neighbouring Africa is already supplied by plants in Kenya and South Africa (Section 1, Appendix 9). Furfural production in Mauritius is not considered further.

Sugarcane wax

4.47 Sugarcane wax is a natural vegetable wax and competes in the animal and vegetable wax market. The total size of this market is around 20 000 t/y; two thirds is accounted for by the vegetable waxes, of which carnauba and candelilla are the most important. Sugarcane wax is only traded in very small quantities.

4.48 The long-term trend in the natural wax markets has been a decline in volume in the face of increasing competition from synthetics. The potential supply which could be obtained from the world sugarcane crop far exceeds that of the other vegetable waxes. However, in view of limited market outlets, production has not proved profitable. The trend in the market is not expected to change (Section 2, Appendix 9).

Livestock products

4.49 Livestock, in particular ruminants, are consumers or potential consumers of many sugarcane by-products. Within the market analysis it is necessary to illustrate that sufficient demand exists for livestock products in Mauritius to absorb all locally produced supplies. Since sugarcane by-products are fed principally to cattle and deer rather than to other livestock, the analysis has concentrated on the markets for beef, milk and venison.

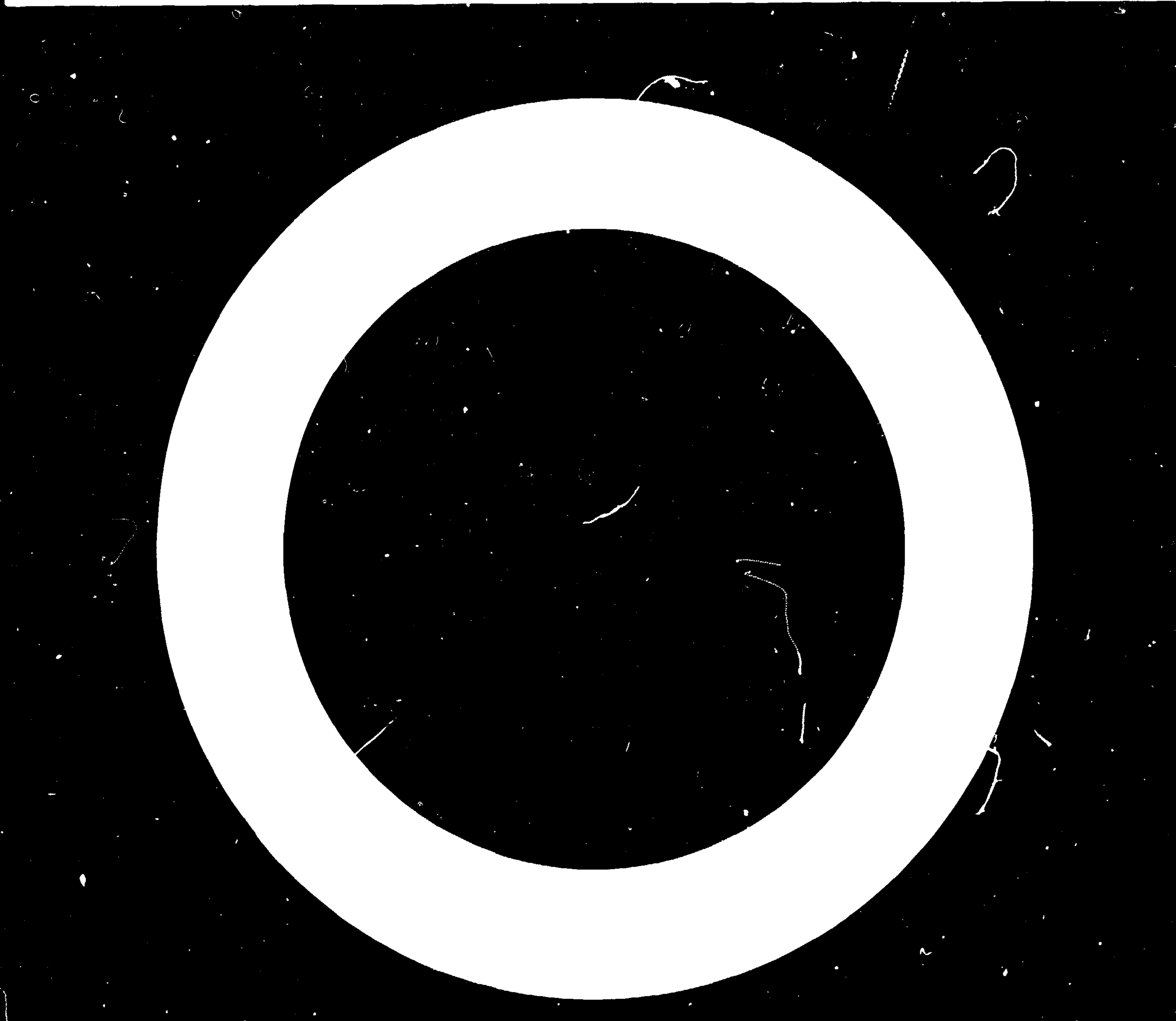
4.50 Present local production of livestock products accounts for only a small proportion of total consumption. In 1980 local beef production accounted for 12% of total beef and beef product consumption, whilst local production of milk was only 7% of total milk consumption.

4.51 Forecasts in para 6.09, Appendix 4 show that by 1990 locally produced beef will account for no more than 19% of total consumption. No detailed forecasts were made for milk but in view of the difficulties likely to be experienced in increasing production, imports will continue to dominate consumption. Deer farming is still in its early stages in Mauritius; increases in production are not likely to be constrained by the market size before 1990.

4.52 Locally produced livestock products will continue to find a market in Mauritius. The potential utilisation of sugarcane by-products for feeding is therefore not constrained by market size.

4.53 Certain marketing aspects, however, are acting as constraints to production of livestock. The Mauritius Meat Authority (MMA) calculated the cost of production of finished cattle ex-farm to be Rs18.13/kg liveweight ($1.77 - para 5.13, Appendix 4). However, MMA is unable to guarantee that producers receive this price. Until MMA is able to exercise the powers it legally possesses it is almost impossible to ensure that producers get a fair and guaranteed price for their slaughter livestock.

4.54 Similarly the price of milk is fixed by Government at Rs2/ℓ ($0.20) whilst production costs are estimated to be of the order of Rs5-6/ℓ ($0.49-0.59 - para 5.10, Appendix 4). Imported milk powder retails for the equivalent of Rs1.7/ℓ ($0.17). Any increase in liquid milk prices to bring them more in line with production costs would need to be accompanied by a levy on imported milk, otherwise local production would be adversely affected (paras 5.10-5.14, Appendix 4). The markets for livestock products are described and the possibilities for an expanding livestock industry are considered in Section 6, Appendix 4.



5. A STRATEGY FOR THE DEVELOPMENT OF BY-PRODUCT INDUSTRIES

General conclusions from technical and market considerations

5.01 The following general conclusions may be drawn:

a) given the predicted behaviour of world markets, it would be in the interests of no party in Mauritius to use mature sugarcane or cane juice for any purpose other than sugar manufacture;

b) unproven technologies should in general be avoided; however, it may be desirable to undertake pilot projects in order to elucidate the technical and economic problems in Mauritius of processes whose application elsewhere appears promising;

c) operations requiring large capacity plants to be viable and having limited or doubtful export markets are unlikely to succeed: these include all chemicals and paper manufacture;

d) operations requiring small plants and with the prospect of expanding world markets should be examined more closely: the most promising is the manufacture of charcoal from bagasse;

e) projects whose objective is the utilisation of sugarcane by-products to produce energy that will replace imports are of particular value and should be commenced as soon as they become economically and financially viable; these include the production of ethanol from molasses and optimising the use of bagasse for electricity generation;

f) there are both economic and social needs to develop the livestock industry and to expand its use of sugarcane by-product feeds;

g) the services of MSIRI and of individuals within U of M and the sugar industry should be more fully employed in investigating and advising on new and additional uses for sugarcane by-products and the technologies concerned with their production and use; and

h) on account of the multiplicity of options and the conflicting economic interests of potential users of sugarcane by-products it is essential that Government establish, at the highest level, an Authority whose task it would be to develop the national exploitation of sugarcane by-products - a major national resource.

Selection of sugarcane by-product industries for development

5.02 The following processes or possible uses of sugarcane by-products have been eliminated from further consideration, either for technical reasons (Chapter 3), marketing reasons (Chapter 4) or because they are already used or are being investigated.

	Reasons for elimination
Sugarcane tops	
- Use of dried tops as a livestock feed or fuel	Technical
- Production of leaf protein	Technical
Sugarcane separation	
- The 'Comfitn' process	Technical
Fly ash, furnace ash and filter mud	
- Fly ash	Under investigation by MSIRI
- Furnace ash as a fertiliser	Present use
- Filter mud as a fertiliser	Present use
- Wax from filter mud	Marketing
Molasses	
- Potable alcohol for export	Marketing
- Baker's yeast	Technical and marketing
- Fodder yeast	Technical and marketing
- Acetic acid	Marketing
- Citric acid	Technical and marketing
- Monosodium glutamate	Technical and marketing
- Chemicals derived from ethylene (ethanol as a feed stock)	Technical and marketing
- Other chemicals not obtained by fermentation	Technical and marketing
Bagasse	
- Producer gas	To be investigated by MSIRI
- Biogas	Technical
- Pulp and paper	Technical and marketing
- Fibreboard	Existing factory
- Medium density fibreboard	Marketing
- Cement bonded board	Technical and marketing
- Furfural	Technical and marketing
- Deep litter	Present use
- Fertiliser	Present use

5.03 The following processes and uses of sugarcane by-products are recommended for further study. The list is considerable and priorities will need to be determined.

<u>Sugarcane production</u>	
Interline cropping	Rapid development of maize production; further investigation of oil-seed crops.
Fodder cane	Further development as a livestock feed in irrigated areas of the drier zone.
<u>Sugarcane tops</u>	
Fresh and ensiled tops	Further pilot studies on methods of collection and utilisation.
<u>Filter mud</u>	
Use as a livestock feed	Further pilot studies on wet feeding and use as a source of trace elements.
<u>Molasses</u>	
Ethanol as a fuel	A major long-term project requiring detailed planning and large sums of capital.
Disposal of vinasse by anaerobic digestion	Pilot trials particularly to study the anaerobic digestion of vinasse as this process is a net producer of energy.
Improvements in the performance of the older distilleries	Some technical assistance required.
As a livestock feed	Further field studies are required on the use of molasses fed at relatively low levels in ruminant rations and at higher levels than were used in the past in pig and poultry rations.

Bagasse

Use for electricity generation	A major long-term project requiring detailed planning, and large sums of capital.
Pelleting surplus bagasse	Detailed feasibility and pilot plant studies to be conducted as soon as possible.
Production of charcoal	Detailed feasibility and pilot plant studies.
Particle board	Some financial and technical support if the factory reopens.
As a livestock feed	Further studies of methods of economically upgrading the nutritive value of bagasse.
Extraction of protein from sugarcane juice	A detailed pilot plant study.

Requirements for possible viable industries

5.04 Use of existing facilities There are advantages in siting almost all production processes at sugar factories, firstly because of the availability of energy inputs, and secondly because of the lower transport costs of raw materials. Only in the case of electricity generation might there be an advantage in economy of scale, by establishing a central thermal station to which bagasse pellets could be transported. An ethanol distillery would also need to be centralised in the sense that molasses would have to be transported to it. All other operations would use only limited quantities of raw materials and these would be available at individual sugar factories.

5.05 Projects involving livestock and the feed industry should be conducted at sugar estates, at cooperatives owning livestock or at feed mills.

5.06 Other infrastructure The ability to locate projects in or adjoining existing facilities minimises the need for other infrastructure. The national electricity transmission system would need further development; this would be true whatever option CEB takes to meet future demand. An important requirement of the ethanol distillery is an economic and efficient effluent disposal system: anaerobic digestion of vinasse may prove to be feasible. Other requirements are alterations to the oil companies' bulk terminals, transport, and filling stations in the event of an ethanol/gasoline mixture being produced, and transport for bagasse or pellets to be used in electricity generation. If pellets are used, this requirement could be met by using the existing raw sugar trucks.

Location of projects

5.07 Electricity generation developments at the factories would be sited primarily according to the benefit/cost ratios at particular factories. Transmission line development would of course be an added cost, and this would probably vary according to the factories chosen.

5.08 The bagasse pelleting plant presently operating in Hawaii has a capacity of 70 t bagasse/hr, which would require a factory output of 1 400 t bagasse/d in a 20-hour day. F.U.E.L produces about 1 300 t bagasse/d. Other factories would need to instal smaller plants, which have yet to be designed and manufactured; alternatively bagasse would have to be transported.

5.09 A pilot charcoal plant would only require 7.5 t bagasse/hr, just over 10% of the throughput of a pelleting plant. Its location would be determined by commercial considerations.

5.10 An extended ethanol distillery to produce an extra 50 000 ℓ/d alongside the existing Beau Plan distillery would not necessarily be the most advantageous location. Cost savings would not be material. A sugar factory should be chosen as a site for the ethanol distillery where firstly the effluent problem would be capable of solution, and secondly the overall costs of transport of molasses for distillation and for export would be minimised.

5.11 Livestock feed projects would be located on sugar or other estates, at livestock cooperatives or at feed mills.

5.12 From the details provided above it is obvious that an agro-industrial complex in a single location would not be feasible.

Project interrelationships

5.13 Projects will sometimes inevitably compete with each other for sugarcane industry by-products. In several cases the amounts involved are small or, as in the case of cane tops, there is no present major use. The following data are material to this problem (ie 10 000 t or more of by-product will be used).

Molasses:	Animal feed requirements	present	6 000 t/y
		future (1990)	43-83 000 t/y
	Ethanol distillery	present	11 000 t/y
		future	71 000 t/y

The present production of molasses averages 191 000 t/y.

The benefits of using molasses and small amounts of other sugarcane by-products in animal feeds are difficult to quantify; however the development of the livestock industry has a high economic priority. Even if the ethanol distillery is established, there would still be a surplus of molasses for export over and above the quantities used by the animal feed industry and the proposed ethanol distillery.

Bagasse:	Woodex pelleting plant pilot project	160 000 t/y
	Full scale production	All bagasse surplus to internal factory requirements
	Charcoal pilot project	33 000 t/y

The present production of bagasse averages 1.73 M t/y.

Energy project alternatives

5.14 The principal contribution that sugarcane industry by-products can make to the economy of Mauritius is clearly in the production of energy; it is in this sector that the two major projects are to be found, ethanol and electricity. Charcoal is a minor energy project. In all these projects there are alternatives to consider.

5.15 Ethanol The three alternatives proposed in para 3.18 are:

Option A	a 107 000 ℓ/d	distillery operating during the sugar crop season only
Option B	a 50 000 ℓ/d	distillery operating 300 d/y; and
Option C	a 30 000 ℓ/d	extension to the existing 20 000 ℓ/d Beau Plan distillery operating as Option B.

Option C is not viable because of the loss of revenue from potable alcohol. The option to build a 50 000 ℓ/d extension to Beau Plan was not considered, since, in financial terms, it would not be materially different to Option B.

5.16 The problem of the disposal of vinasse must be solved. The alternatives are listed in para 3.19, Chapter 3. A 107 000 ℓ/d distillery would produce 1 500 m^3/d of vinasse. In order to dispose of this quantity through an irrigation system, given a range of disposal of 50-150 m^3 of vinasse/ha/y, an irrigated area of between 2 250 and 6 750 ha would be needed. This emphasises the point about the location of the distillery; it also indicates the need to evaluate the alternatives. Of these anaerobic digestion is the most attractive in terms both of energy and of capital costs; the methane can be used in the sugar factory boiler or in the distillery itself. The technology is untried in Mauritius; however, it would be desirable to operate a pilot plant at Beau Plan, given the likely lead time for any power alcohol project.

5.17 The use of bagasse pellets in the out-of-crop season instead of fuel oil is also considered. With the opportunity cost of bagasse measured in terms of coal there is a substantial cost saving over using fuel oil out-of-crop.

5.18 <u>Electricity</u> There are two levels of alternatives with the generation of electricity from bagasse. The first level involves a choice between production:

- during the crop season only; and
- year-round.

The latter option is preferred (para 3.34, Chapter 3).

5.19 The second level of alternatives assumes year-round operation, upgrading the process sections of the factories, and the installation of bagasse pelleting facilities. Three alternatives are proposed in para 3.37, Chapter 3:

Option A: A central bagasse pellet fired 30 MW power station;

Option B: Regional bagasse pellet fired power stations at 3 sugar factories using high pressure boilers;

Option C: Increased power generation at the factories using existing boilers.

These are compared with a central coal fired 30 MW power station. Option C has the lowest capital and operating costs/Kwh.

5.20 If year round operation is not feasible the alternatives revolve around how much money the economy can invest in substituting bagasse for imported fuel oil during the crop season. The price of fuel oil price relative to other costs will be relevant. Improvements would be in three steps. The second and third would replace the existing sugar boilers by more efficient equipment. The needs have not been assessed on the basis of individual factories, but it is certain that capital costs would be excessive unless the boilers were replaced as part of normal factory rehabilitation.

5.21 Charcoal The need to evaluate the horizontal and vertical kiln methods of production has been mentioned in Chapter 3, and is discussed fully in Section 1, Appendix 7B. The evaluation would be necessary in any feasibility study of charcoal production in Mauritius.

Institutional support

5.22 In order to ensure that the proposed projects are conducted using minimal external assistance and hence in the most economic manner it will be necessary to mobilise the country's technical skills. Mauritius is fortunate in this respect at present; there is a considerable body of expertise in the utilisation of sugarcane by-products. It is suggested that the proposed Mauritius Research Council (MRC) should be established at as early a date as possible and that it be authorised to control the funds (from whatever source) that will be required to conduct the investigational phases of any of the proposed projects. The MRC would then be able to organise the investigation work in a rational manner providing specific grants to MSIRI, the relevant divisions of the Ministry of Agriculture and Natural Resources and the Environment, to individuals and/or departments in U of M and to individuals and/or firms in the private sector.

5.23 A programme for the development of sugarcane by-product resources would include more than investigation work and pilot plant studies, and would need to be organised and coordinated by an Authority constituted at the very highest level in Government. It should be the responsibility of this Authority to advise Government as to how the necessary funds for financing the programme could be secured. It would also define priorities, decide what funds should be allocated to the MRC for the investigation and pilot trial phases of the programme, and consider as to how mixed public/private enterprises (such as will be required for the production of electricity from surplus bagasse and possibly of ethanol for motor fuel from molasses) should be organised, funded and controlled. The Authority would be assisted in this latter task by a Central Energy Planning Committee as proposed in para 11.08, Appendix 7A.

6. PROJECT PROPOSALS AND COSTS

6.01 In this Chapter attention is concentrated on the worthwhile projects that have been identified in para 5.03, Chapter 5. In some instances considerable investigation work is still required, while in others a stage has been reached at which the conduct of pilot trials would be the next rational step; in the case of a few projects the major constraint is the provision of adequate capital.

6.02 Capital costs only of proposals are included. Operating costs of pilot plants, or early losses at the ethanol plant, may be added at the feasibility study stage if required.

6.03 In order to facilitate reference to data, proposals for individual projects are listed below in the same order as the details concerning them appear in the Appendices.

<u>Sugarcane production</u>

6.04 <u>Interline cropping</u> Rapid development of the maize crop depends upon solution of the problems of mechanised harvesting and the establishment of an additional three drying plants. Equipment for mechanisation of harvesting is being developed, and an application is at present being made for overseas aid for the funding of drying plants. If, however, the application is unsuccessful a project for the development of three additional drying plants would be recommended.

6.05 <u>Fodder cane</u> It is recommended that the industry itself should encourage the production in a suitable climatic zone of fodder cane on estates that raise livestock.

<u>Livestock feeds</u>

6.06 In Section 7, Appendix 5, it is concluded that additional investigation work and pilot trials are required before some of the problems of producing and feeding sugarcane by-products to livestock can be resolved. These problems may be classified into two groups - those concerned with:

a) farming practice; and

b) the agro-industrial technology of producing livestock feeds from sugarcane by-products.

The Ministry of Agriculture and Natural Resources and the Environment should be responsible for investigating the majority of the first group of problems, whilst MSIRI and U of M should study the second group.

6.07 <u>Proposals for investigational projects that should be the responsibility of the Ministry of Agriculture</u> The following investigations are required at field sites as suggested in Chapter 3 and paras 7.15-7.17, Appendix 4.

a) <u>Utilisation of cane tops</u>

i) A study of the most suitable methods of collection of cane tops in the field and the effect of the use of ripeners and burning on their nutrient content;

ii) a study of the use of ammonia and urea in the ensilage of cane tops.

b) <u>Utilisation of filter mud</u> A study of the most suitable methods of feeding wet filter mud and particularly its use in the ensilage of cane tops; in association with a feed mill, a study of the use of dried filter mud as a substitute for imported trace element supplements in livestock rations.

c) <u>Utilisation of molasses</u> Studies on the feeding of roughages with the addition of low levels of molasses; in association with a feed mill, a study of the possibility of using higher levels of molasses in pig and poultry rations (up to 20% of the total ration for poultry and up to 30% for pigs ; also in association with a feed mill the utility of molasses/urea/mineral blocks for ruminant nutrition on rough grazings and in integrated cattle or deer/forestry management systems.

6.08 The estimated cost of such a programme would be:

Project	Foreign exchange component Rs'000	($'000)	Local costs Rs'000	($'000)	Total costs Rs'000	($'000)
Utilisation of cane tops and molasses. Items (a) and (c) para 6.07	213	(21.0)	226	(22.0)	439	(43.4)
Utilisation of filter mud. Item (b) para 6.07			219	(21.4)	219	(21.4)
Totals	213	(21.0)	445	(43.4)	658	(64.5)

Further details of the costs of these projects are provided in para 7.10, Appendix 5.

6.09 Proposals for investigation projects and pilot plants that should be the responsibility of MSIRI and/or U of M. It is recommended that the following investigations and pilot plants are required:

a) A technical assessment of alternative methods of treating bagasse in order to improve its nutritive value (Section 3, Appendix 5), followed by the installation of a pilot plant (assessed as the most suitable) located at the site of a large-scale livestock project;

b) a pilot trial at a sugar factory to evaluate the technical and economic factors concerned in the extraction of protein from sugarcane juice, using a continuous centrifugal method.

6.10 The *ad hoc* Committee set up to establish research priorities, or the Mauritius Research Council (MRC) if it is established, should decide the relative roles of MSIRI and U of M in the conduct of this work. It is estimated that the cost of the programme would be:

Project	Foreign exchange component Rs'000	($'000)	Local costs Rs'000	($'000)	Total costs Rs'000	($'000)
Assessment of alternative methods of treating bagasse; installation and operation of a pilot plant Item (a) para 6.09	218	(21.3)	355	(34.6)	573	(55.9)
Pilot trial on extraction of protein from sugarcane juice Item (b), para 6.09	888	(86.6)	398	(38.8)	1 286	(125.4)
Totals	1 106	(107.9)	753	(73.4)	1 859	(181.3)

Further details of costs of these projects are provided in para 7.10, Appendix 5. Terms of reference of these studies (and of others proposed in the report) are provided at the end of this volume.

6.11 <u>Proposal for the employment of a livestock production expert</u> It is recommended that an experienced practical livestock production expert is employed for two years (para 7.09, Appendix 5). His responsibilities would be to work with the producers to increase production, and to supervise and extend to the commercial sector the programmes proposed above. He would be responsible to MRC. The cost of this proposal would be:

Project	Foreign exchange component Rs'000	($'000)	Local costs Rs'000	($'000)	Total costs Rs'000	($'000)
Livestock production expert	1 540	(150)			1 540	(150)

Fermentation and distillation products

6.12 Ethanol for fuel The decision by Government as to whether a plant should be established to produce ethanol for fuel purposes will depend partly on economic and financial factors, especially the relation between the export price of molasses and the import price of gasoline (Appendices 6A and 10) and partly on non-economic considerations. At present estimates of price movements, an ethanol project does not have an adequate financial return and it is recommended that the project be deferred.

6.13 The preferred production option is a 107 000 ℓ/d plant operating during the crop season only. It is recommended that a pilot plant for the anaerobic digestion of vinasse be established at Beau Plan. It is important that the problem of disposing of vinasse should be solved before a decision is taken with regard to the establishment of the 107 000 ℓ/d ethanol distillery and it is likely that some time will elapse before the relative prices of molasses and gasoline move significantly in favour of the establishment of the ethanol distillery.

6.14 Improvements in the performance of the older distilleries It is recommended that some technical assistance should be provided to help the older distilleries improve their productivity. One man-month of assistance by a distillery expert should be adequate.

6.15 Project costs It is considered that the costs of these proposals would be as follows:

Project	Foreign exchange component		Local costs		Total costs	
	RsM	($M)	RsM	($M)	RsM	($M)
Pilot plant for anaerobic digestion of vinasse, para 6.13	6.0	(0.59)	1.0	(0.09)	7.0	(0.68)
Technical assistance to existing distilleries para 6.14	0.072	(0.007)			0.072	(0.007)
Total	6.072	(0.597)	1.0	(0.09)	7.072	(0.687)

The capital costs of the recommended option for an ethanol distillery (establishment to be deferred) are provided in para 6.28.

Energy from bagasse

6.16 Four projects concerned with energy production from bagasse are proposed, of which three relate to electrical energy.

6.17 Improvements in energy efficiency at the sugar factories Further investment in the process sections of the 15 larger sugar factories (Groups II and III) are required in order to optimise the production and utilisation of steam and hence provide an increased surplus of bagasse. The investments required are described in Section 8, Appendix 7A and listed by factories in End Table 12 of that Appendix.

6.18 Pelleting of bagasse Advantages that would accrue if bagasse could be pelleted have been summarised in Chapters 3 and 5 and are detailed in Section 7, Appendix 7A. A feasibility study is required to ascertain the most economic method of pelleting bagasse to be followed by the establishment of a pilot pelleting plant at one of the sugar factories where there is an adequate supply of bagasse. It is estimated that the study would take 10 man-months. Terms of reference of the feasibility study are provided at the end of this volume.

6.19 If the feasibility study and the pilot plant for bagasse pelleting proposed in para 6.16 are satisfactory and it is decided to use bagasse pellets as fuel at a power station, investment would be required for pelleting plants at each of the 15 sugar factories.

6.20 Generation of electrical energy from bagasse pellets The preferred option is to instal three 10 MW factory power stations at Group V sugar factories using existing boilers (of which one is already operating at Medine).

6.21 Estimated project costs using Option C are as follows:

Project	Foreign exchange component RsM	($M)	Local costs RsM	($M)	Total costs RsM	($M)
Improvements in the process sections at 15 sugar factories, para 6.17	10.29	(1.0)	1.14	(0.1)	11.43	(1.1)
Feasibility study of the most economic method of pelleting bagasse, para 6.18	0.64	(0.063)			0.64	(0.063)
Pilot pelleting plant at a sugar factory, para 6.18	26.1	(2.55)	2.9	(0.28)	29.0	(2.83)
Equipping 15 sugar factories with pelleting plant, para 6.19	276	(27)	31	(3)	307	(30)
Establishment of 2 10 MW factory power stations, para 6.20	76	(7.4)	4	(0.4)	80	(7.8)

6.22 Charcoal production A feasibility study of the possibility of producing charcoal from bagasse is recommended. If the result is favourable a pilot plant, incorporating the process recommended in the feasibility study, should be established at a sugar factory where an adequate surplus of bagasse exists. The study is estimated to take 6 man-months. Terms of reference are provided at the end of this volume.

6.23 It is estimated that the costs of the feasibility study and pilot plant would be:

Project	Foreign exchange component Rs'000	($'000)	Local costs Rs'000	($'000)	Total costs Rs'000	($'000)
Feasibility study of most suitable method of producing charcoal from bagasse, para 6.22	384	(37.5)			384	(37.5)
Pilot charcoal plant, para 6.22	14 760	(1 440)	1 640	(160)	16 400	(1 600)
Totals	15 144	(1 477.5)	1 640	(160)	16 784	(1 637.5)

Fibre products

6.24 Particle board factory The decision to reopen will be a commercial one by the existing investors, principally the Development Bank of Mauritius. The amount of extra capital to be found is small, being estimated as Rs 600 000 ($59 000), and should be provided locally; a small amount of start-up costs will be necessary.

6.25 The following visits by a suitable technical expert are suggested:

1st year	One month before and two months after recommissioning the plant and one month towards the end of the first year of operation.
2nd and 3rd years	One month in each year.

The total is 6 man-months.

6.26 The costs of a technical assistance project would be as follows:

Project	Foreign exchange component Rs'000	($'000)	Local costs Rs'000	($'000)	Total costs Rs'000	($'000)
Technical assistance to the particle board plant, para 6.25	384	(37.5)			384	(37.5)

The estimated cost of technical assistance assumes that accommodation and transport would be made available at St Antoine.

Summary of costs of proposed projects

6.27 Proposed projects are liste[illegible] two sections. The first consists of studies, techn[illegible]ssistance and pilot plants which could start immediately; it includes the improvements to the process sections at 15 sugar factories. The second consists of the major investments which would depend on economic circumstances and/or the outcome of the feasibility studies and the operation of the pilot plants. The costs of projects that should be started as soon as possible are:

Project	Foreign exchange component RsM	($M)	Local costs RsM	($M)	Total costs RsM	($M)
Livestock feeds						
Ministry of Agriculture	0.213	(0.021)	0.445	(0.043)	0.658	(0.064)
MSIRI and/or U of M	1.106	(0.108)	0.753	(0.073)	1.859	(0.181)
Livestock production expert	1.540	(0.150)			1.540	(0.150)
Fermentation and distillation						
Pilot plant for anaerobic digestion of vinasse	6.0	(0.59)	1.0	(0.09)	7.0	(0.68)
Technical assistance to distilleries	0.072	(0.007)			0.072	(0.007)
Energy from bagasse						
Improvements in the process sections at 15 sugar factories	10.29	(1.0)	1.14	(0.1)	11.43	(1.1)
Feasibility study of the most economic method of pelleting bagasse	0.64	(0.063)			0.64	(0.063)
Pilot pelleting plant at a sugar factory	26.1	(2.55)	2.9	(0.28)	29.0	(2.83)
Feasibility study of production of charcoal from bagasse	0.384	(0.037)			0.384	(0.037)
Pilot charcoal plant	14.76	(1.44)	1.64	(0.16)	16.4	(1.6)
Fibre board						
Technical assistance to particle board factory	0.384	(0.037)			0.384	(0.037)
Totals	61.489	(6.003)	7.878	(0.745)	69.367	(6.747)

It is not possible to phase these costs since starting dates depend upon decisions still to be made by Government.

6.28 The estimated costs of projects that will be deferred until feasibility work is complete or the economic and financial conditions are suitable are:

Project	Foreign exchange component RsM	($M)	Local costs RsM	($M)	Total costs RsM	($M)
Fermentation and distillation products						
107 000 ℓ/d ethanol distillation plant	90	(8.8)	32	(3.1)	122	(11.9)
Gasoline company works	2	(0.2)	1	(0.1)	3	(0.3)
Vinasse digester (if needed)	24	(2.4)	3	(0.3)	27	(2.7)
Energy						
Equipping factories with pelleting plants	276	(27)	31	(3)	307	(30)
Establishment of 2 10 MW factory power stations	76	(7.4)	4	(0.4)	80	(7.8)
Totals:						
without vinasse digester	444	(43.4)	68	(6.6)	512	(50.0)
with vinasse digester	468	(45.8)	71	(6.9)	539	(52.7)

Funding of projects

6.29 Recommendations as to possible methods of funding the proposed projects are as follows:

a) Livestock feeds: Ministry of Agriculture component Might be partially funded by UNDP as a final phase of the current FAO/UNDP livestock project.

b) Livestock feeds: MSIRI/U of M component These projects could also be partially funded by UNDP as a UNIDO project if country programme funds are available and if it is agreed to use them for this purpose.

c) <u>Livestock production expert: MRC</u> This could be funded by a two year extension to the FAO UNDP livestock project, giving a good opportunity to finalise the work done on that project.

d) <u>Fermentation and distillation products: pilot plant for the anaerobic digestion of vinasse</u> Could be funded through a bilateral or multilateral aid programme. As the project would be of interest to many other sugar producing countries UNIDO could possibly seek regional or global funds from UNDP. A further possibility is funding by grant from the United Nations Capital Development Fund (UNCDF).

e) <u>Fermentation and distillation products: improvement in the efficiency of older distilleries</u> One man-month of technical assistance could be provided by UNIDO.

f) <u>Fermentation and distillation products: 107 000 t/a ethanol plant</u> The plant would be owned by Government or by a joint enterprise and it would be financed in what Government considers is the most appropriate manner. Possibly a consortium of multilateral banks (IBRD, ADB) and private banks would channel loans through the Development Bank of Mauritius (DBM). (It has been recommended that this project be deferred for the time being).

g) <u>Energy: improvements in the process sections of 15 sugar factories</u> These could be funded by special loans to the factories by DBM.

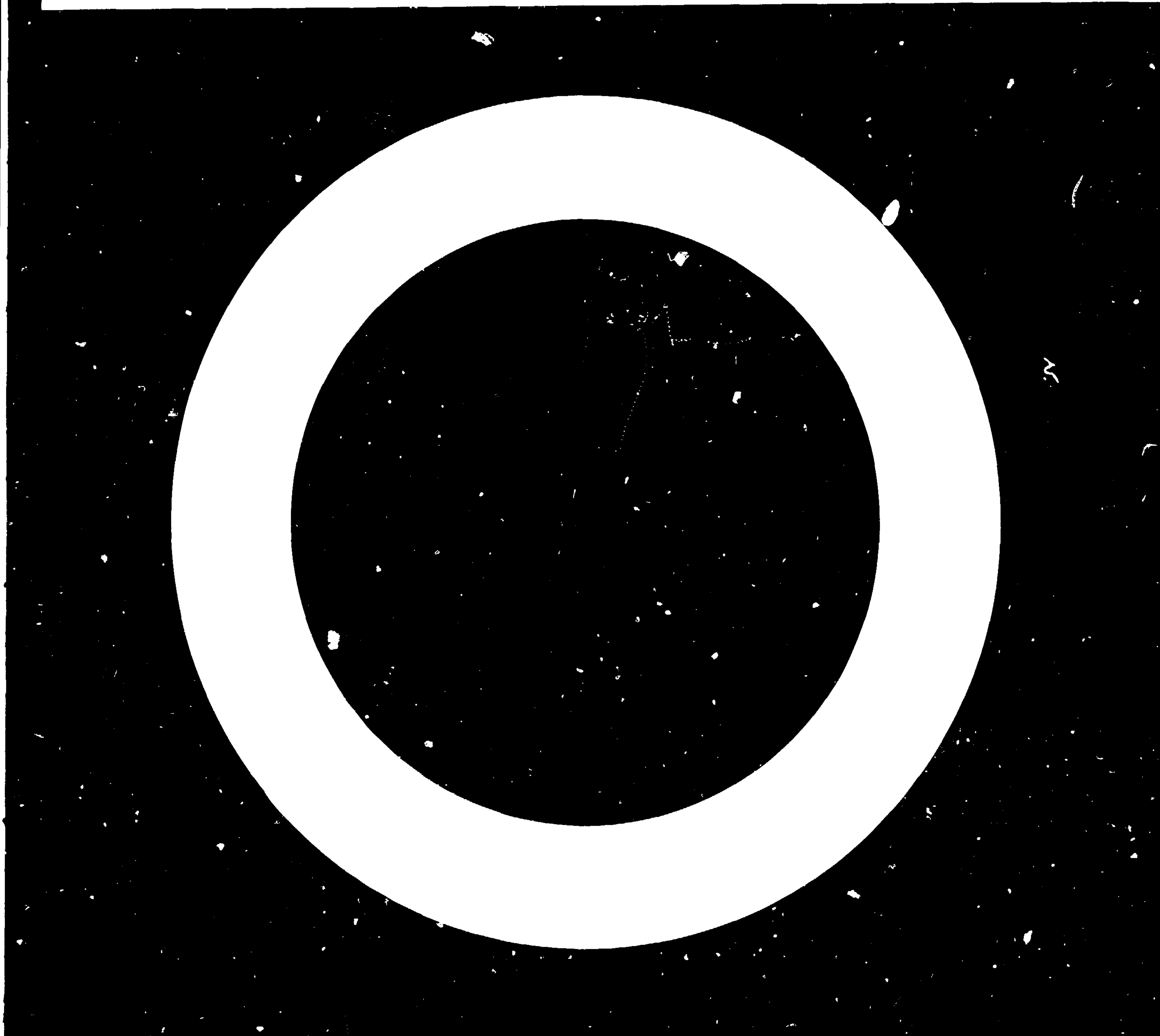
h) <u>Energy: feasibility study of bagasse pelleting plants</u> It is suggested that UNIDO might fund this study seeking regional or global UNDP funds, as it would be of interest to many other sugar producing countries.

i) <u>Energy: establishment of a pilot bagasse pelleting plant</u> This could be funded in the same manner as the above project.

j) <u>Energy: equipment of sugar factories with pelleting plant and two 10 MW generating sets</u> This large investment would be made partly in the private and partly in the public sector. The project would probably be financed in a similar manner to the ethanol plant ((e) above).

k) Energy: charcoal from bagasse It is possible that the feasibility study of the most suitable bagasse carbonisation plant could be funded by UNIDO. Other funds, bilateral or multilateral, would be needed to finance the pilot plant.

l) Particle board The cost of reopening the St Antoine factory would be met from local private sources. The technical cooperation input could be provided by the Tropical Products Institute and funded by the British Government or alternatively by UNIDO using experts of their choice.



7. JUSTIFICATION AND BENEFITS

Introduction

7.01 In the previous chapter the proposed projects were divided into two categories:

a) investigation work, feasibility studies, pilot plants, improvements to sugar factory process sections, and technical assistance, which could conveniently be started quite soon; and

b) major projects whose feasibility would depend on the results of some of the studies in the previous category and/or on economic circumstances.

Apart from the improvements to the process sections (whose costs are included in the financial analyses of the electricity projects), the first category of projects are not justified by financial or economic analyses which involve the estimation of benefits and costs. But they are necessary if the by-products sector is to expand. Further, the studies and equipment recommended for the development of livestock feeds are essential if there is to be an expanding livestock sector in the economy of Mauritius.

Financial analyses

7.02 The second category of projects are the major ones - production of ethanol from molasses to provide a constituent of a motor fuel, and of electricity from bagasse. Financial analyses of these have been carried out and are tabulated and summarised in Appendix 11.

7.03 The general assumptions made in the analyses are shown in Appendix 11, and the cost details and technical assumptions of both are in Appendices 6A and 7A respectively. The most important assumptions are that:

a) the measure of financial performance is the internal rate of return (IRR - the rate of interest at which the present values of costs and benefits are the same) over 25 years, with no residual values; and

b) constant July 1981 prices are used, adjusted for the subsequent devaluation; however in the case of ethanol, it has been assumed that the prices of gasoline and molasses will both rise by 3%/y in real terms.

7.04 Ethanol The unit costs of producing ethanol, including depreciation and interest, are:

	Rs c	US¢ c
Option A	4.39	42
Option B	4.65	45
Option C	4.67	45
Option A with vinasse digester	4.59	45

7.05 The rate of return on Option A is 7.8%. The rates of return on the alternatives are:

	IRR
Option A delayed to 1990	12.5%
Option B	2.9%
Option C	0
Option A with vinasse digester	6.3%
Option B with bagasse pellets	7.6%
Option A at constant 1981 prices	1.1%
Options B and C at constant 1981 prices	0

Option A is not considered a viable proposition at the moment but it is could become so in the 1990s. Option B is less attractive than Option A because of the need to burn expensive fuel oil out-of-crop. Option C fails because of the cost of the foregone potable alcohol. The vinasse digester, although attractive in energy terms, has an adverse financial effect since the methane replaces cheap factory steam. Option B using bagasse pellets instead of fuel oil out-of-crop appears almost as attractive as Option A, but in this analysis the foregone electricity not generated by burning bagasse pellets in a power station has not been taken into account.

7.06 Section 3, Appendix 11 shows rates of return on the basis of other assumptions as to prices and price movements. End Tables 1-4 show cash forecasts for Options A, B and C and for Option A with the vinasse digester.

7.07 <u>Electricity</u> The unit costs of generating electricity, including depreciation and interest, are:

	Rs/kWh	USc KWh
Option C	0.420	4.0
Option A	0.560	5.4
Option B	0.516	5.0
Coal fired power station	0.688	6.6

7.08 The rate of return on Option C is 26.4%. The rates of return on the alternatives are:

	IRR %
Option A	21.3
Option B	22.6
Coal fired power station	19.8

From these figures it is clear that Option C represents the best plan for using bagasse for electricity generation in Mauritius. This is confirmed by analysis of the net prevent values of the options.

7.09 Comparisons of the cash forecasts of the bagasse pellet power stations with coal fired give rates of return as follows:

	IRR %
Option A vs coal	23.6
Option B vs coal	34.4

Option C has a low marginal capital cost and hence a very high IRR.

7.10 Section 4, Appendix II gives further details of the financial analysis, and End Tables 5-8 show cash forecasts for the coal fired power station and for Options A, B and C.

Economic analyses

7.11 The financial analyses of ethanol and electricity production have been done on the basis of total systems using purchases from and sales to the outside world. No assumptions have been made as to the ownership and operation of the assets, nor as to the relationships between the parties. The only adjustments to be made to the financial analyses to provide economic ones are therefore for the economic prices of foreign exchange and of unskilled labour.

7.12 Both the inputs and the outputs of the ethanol project are almost entirely in foreign exchange, and there is very little unskilled labour; the economic rates of return are not materially different to the financial ones. The economic rate of return of Option A is 8.5%.

7.13 Most of the inputs to the electricity generation project are imported, whereas the electricity generated is considered to have a 36% foreign component. As with ethanol there would be little or no unskilled labour inputs. The economic rates of return are slightly lower than the financial ones; they are still attractive given the price chosen for sales of electricity, and the ranking of the options is unaltered. The economic rate of return of Option C is 24.9%.

Conclusions

7.14 All the investigation work, feasibility studies, pilot plants and technical assistance in the first category should go ahead. Even though the anaerobic vinasse digester appears unattractive in financial terms, the pilot plant should be built as it may be necessary to add a full-scale one to the 107 00 t/d distillery when a decision is made to go ahead with that project.

7.15 The development of Option C for electricity generation should go ahead when the necessary preliminary studies have been successfully completed. The ethanol project should be deferred until the relationship between the prices of molasses and gasoline gives rise to an acceptable rate of return.

TERMS OF REFERENCE FOR FEASIBILITY STUDIES OF BAGASSE PELLETING, CHARCOAL FROM BAGASSE, AND FOR LIVESTOCK FEED INVESTIGATIONS

TERMS OF REFERENCE FOR FEASIBILITY STUDIES OF BAGASSE PELLETING, CHARCOAL FROM BAGASSE, AND FOR LIVESTOCK FEED INVESTIGATIONS

Feasibility Study of Bagasse Pelleting

Technical considerations

1. Bagasse particle size: the most suitable form of bagasse for pelleting should be investigated; whole, depithed or hammer milled.

2. Methods of handling bagasse prior to drying: these must be investigated with particular reference to the possibility of reducing the moisture content.

3. Required optimal moisture content of bagasse fed to the pelleting machine: the ability of the flue gases at sugar factories in Mauritius to dry bagasse to the required moisture content must be ascertained and any fire risk due to the use of flue gases must be considered.

4. Type of drier: different types should be evaluated in terms of cost of operation and energy efficiency.

5. Density of pellets: optimal density and binding requirements must be ascertained for different types of machine.

6. Methods of storage and transport of bagasse after pelleting must be considered.

Financial considerations

7. The capital costs of different types of plant must be ascertained, including cost of civil work and installation.

8. The possibility of local fabrication of a pelleting machine must be considered: details of imported components would be required.

9. Possibilities for purchase of a second-hand plant should be investigated.

10. Operating costs are required: this should include a study of maintenance costs (including cost of spares), electrical power and labour requirements.

General considerations

11. A technical and financial evaluation of the first year's operation of the Hawaii-based Woodex pelleting plant should be conducted.

12. The Woodex pelleting plant should be examined in order to ascertain whether improvements could be made that would reduce capital and/or operating costs.

13. Investigation of the possibility of building smaller and cheaper machines with a lower capacity, that would be equally efficient, is required as some Mauritius sugar factories have a low output of surplus bagasse.

14. The merits of any other method of compressing and storing bagasse that may be an alternative to pelleting should be examined.

Feasibility Study of Charcoal Production from Bagasse

Technical considerations

15. Bagasse particle size: the possible need to hammer mill bagasse before carbonisation should be investigated.

16. Drying of bagasse: methods of handling bagasse prior to drying should be examined as should the efficiency of different types of drier: the optimal moisture level of the bagasse feed must also be ascertained, taking into account the capacity of the carbonising process and the use of pyrolysis gases.

17. Types of reactor: these should be studied and recommendations made with regard to the relative merits of horizontal and vertical kilns, internal and external heating and any other relevant technical factors.

18. The overall energy balance of bagasse carbonisation systems should be considered and recommendations made on the optimum utilisation of the pyrolysis gases.

19. Extenders and binders: recommendations are required as to those most suitable for use in Mauritius.

20. Alternative products - extended pellets or pressed briquettes: these should be examined with reference to their production costs, quality and marketability.

21. The properties and performance of the product must be examined and compared with competing products, as they must be in no way inferior.

Financial considerations

22. Capital costs: those of different types of plant should be ascertained as should the costs of civil work and installation and the space requirements of the plant.

23. The possibility of local fabrication of part or all of the machinery, and of second-hand purchase must also be considered and commented on.

24. Operating costs: these must be investigated, particularly with regard to maintenance costs (including spares), electrical power and labour requirements.

Market considerations

25. Local and export markets must be investigated.

Livestock Feed Investigations

Investigations to be conducted by the Ministry of Agriculture and Natural Resources and Environment

26. The estimated project costs are very low. This is because it is anticipated that the investigations will mainly take place on sugar estates or elsewhere outside Government livestock stations, where the major part of the costs will be absorbed by the producer as a quid pro quo for the information that will be obtained, and investigative staff will be seconded from the Government's livestock breeding stations.

27. Sugarcane tops A first requirement is to obtain more accurate information than is available at present on the quantity and quality (in nutritive terms) of sugarcane tops. This could be accomplished by requesting field staff at all factories to obtain data by weighing cane and cane tops cut in the field at intervals throughout the harvesting season and forward samples to the Ministry of Agriculture for proximate analysis. At the same time the effects of burning the cane and using ripeners at the beginning of the season on the quantity and quality of cane tops should be ascertained.

28. A second requirement is to ascertain the most suitable method of collecting cane tops in the field, either for feeding green or for ensiling. Economic data are required on four methods of collection:

a) baling of cane tops in windrows followed by loading of the bales onto trailers for transport to the feeding yard or silage pit;

b) use of a forage harvester to pick up cane tops in the windrow, chop them and deliver them into following trailers for transport to a feeding yard or silage pit;

c) loading of cane tops onto trailers at harvest, using the mechanical loading equipment that loads cane, and their transport to the feeding yard or silage pit; and

d) hand selection and carrying of cane tops after harvest.

The effect of the four methods of collection on the nutritional value of the cane tops should also be ascertained. Suitable samples should be taken at intervals and forwarded to the Ministry of Agriculture for proximate analysis.

29. The third requirement is investigation of the most suitable additive to use when ensiling cane tops; molasses or urea. This work will require some small, investigational silos and might most conveniently be conducted at one of the livestock breeding stations in cooperation with an adjacent sugar estate.

30. Use of molasses In addition to investigating the effects of using low levels of molasses in ensiling cane tops, it is suggested in Appendix 5 that two other methods of utilising molasses should be examined.

31. The first investigation is the use of higher levels of molasses than are normally used in pig and poultry rations. This work could best be done in cooperation with a private feed mill - possibly Livestock Feeds Limited. It would be necessary to obtain the consent of a limited number of pig and poultry farmers who purchase feeds from Livestock Feeds Limited to agree to use rations with higher molasses contents for a specific period, and for the cooperators to agree to allow Ministry of Agriculture investigational personnel to measure the productivity, health, etc of the livestock under trial at specific intervals.

32. The second investigation would be a trial of the use of molasses/urea/mineral blocks. It would require two phases. The first phase would be the local manufacture of the blocks by a feed mill - possibly Livestock Feeds Limited. The second phase would be trials of the use of the blocks, using cattle and deer that are at present managed on rough grazings or in forests. The blocks could be placed out in the field and the data required would be the weight of blocks consumed by a specific number of livestock and liveweight gained over a specific period of time by a group of livestock with access to the blocks. The health and reproductive behaviour of the groups of animals with access to blocks should also be recorded. The liveweight gains and health and reproductive behaviour of groups with no access to blocks during the same period should also be recorded, to provide a control group.

33. The use of filter mud When cane tops are ensiled (para 27) an investigation could be conducted on the use of wet filter mud as an additional additive. Medium size silos would be required in order to ensile a sufficient quantity of cane tops to provide enough roughage for a feeding trial. It is suggested that this work be carried out in cooperation with a sugar estate that is already ensiling cane tops using molasses as an additive. It would then be possible to conduct trials comparing the result of feeding the silage on the liveweight gain and health of a group of feeder cattle, compared with a control group of cattle fed silage to which wet filter mud has not been added.

34. It is also suggested in Appendix 5 that dried filter mud could become a source of trace elements for livestock. An investigation of this possibility should also be conducted in cooperation with a feed mill. The first phase of such an investigation would be to collect samples of filter mud from the sugar factories at intervals during the crop season and analyse them for the trace elements listed in End Table 1, Appendix 5 with the addition of selenium. When a sufficient number of samples has been analysed it should be possible to ascertain what the trace element contents of average samples of filter mud might be. At this stage of the investigation it might be considered that the trace element contents of filter mud were unsuitable for inclusion in livestock rations. If this was not so then it would be necessary to commence a series of feeding trials using pigs, broiler and layer poultry, sheep, goats and cattle. These would be conducted as conventional feeding trials, with data being obtained on productivity, reproductive behaviour, health and mortality.

Investigations to be carried out by MSIRI and/or U of M

35. Treatment of bagasse and/or sugarcane tops in order to improve their nutritive value Methods of treatment of roughages in order to improve their nutritive value have been reviewed in Section 3, Appendix 5. It is suggested that the preferred treatment is a Danish type thermo-ammoniation plant.

36. This investigation should be conducted in three phases. In the first phase a limited quantity of baled bagasse should be exported to the UK or Denmark for a critical trial in an operational thermo-ammoniation plant. This phase could be organised using the good offices of the Tropical Products Institute. If the initial trials suggest that it is economic to treat the bagasse (that is that the value of improvement in the nutritive value of the bagasse was greater than the cost of treatment) arrangements would be made to purchase a plant to be installed at a suitable site in Mauritius.

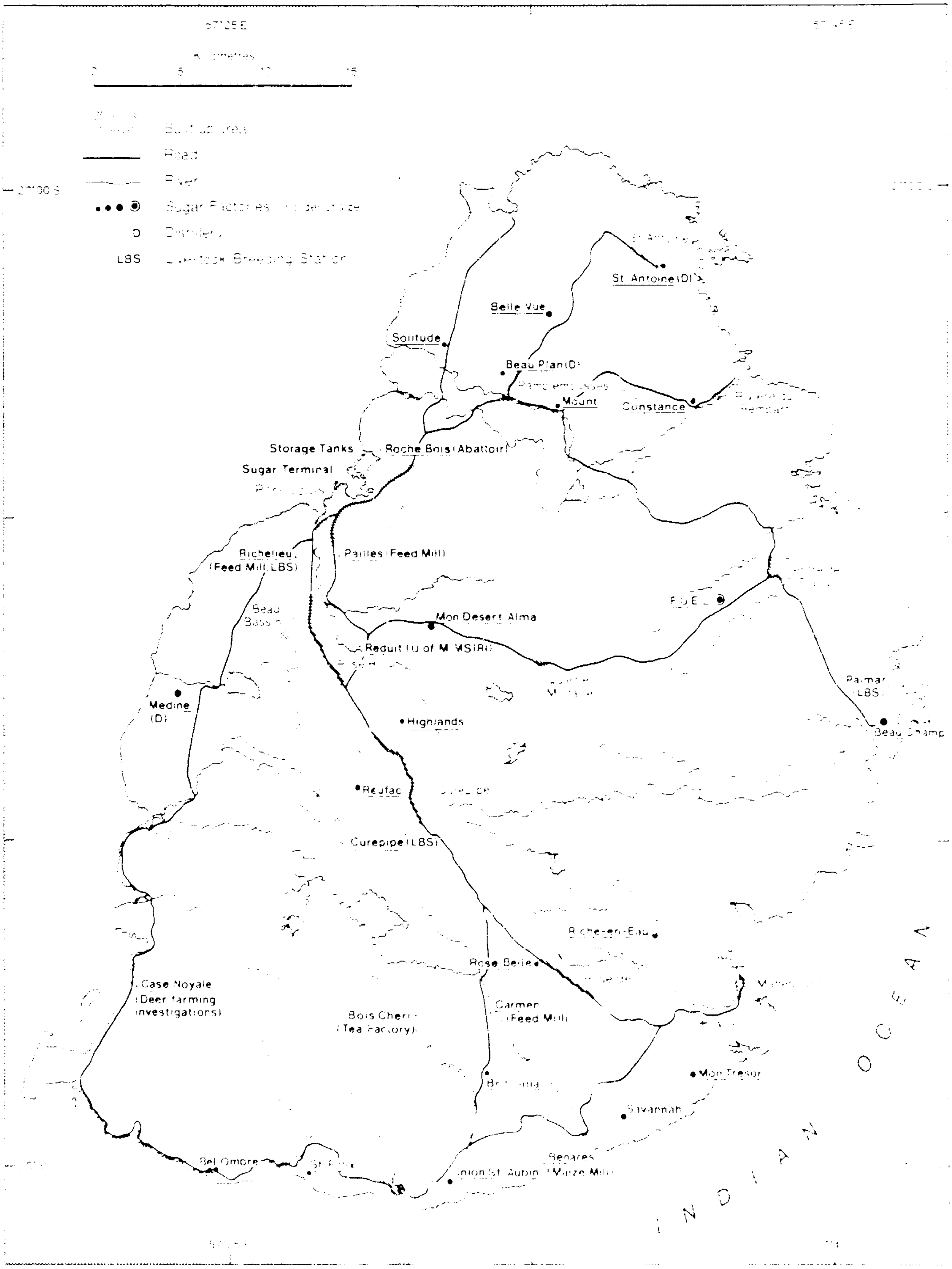
37. A second phase that could be operational at the same time as the first would be the preparation of small quantities of bagasse and cane tops silages treated with ammonia and urea. This phase should be conducted on one of the livestock breeding stations located adjacent to a sugar estate. The original material placed in the silos and the silages produced would be analysed for nutritive value. If the nutritive value of any particular sample was considered to be of a sufficiently high standard then arrangements could be made with one of the estates making and feeding silage to conduct a conventional feeding trial.

38. The third phase would occur if and when a thermo-ammoniation plant was installed in Mauritius. Conventional feeding trials should then be conducted using various types of treated roughage.

Recovery of protein from sugarcane juice

39. It is proposed that MSIRI conduct a trial on the recovery of protein from sugarcane juice using a continuous centrifuge at a sugar factory willing to cooperate. Proposals for problems that might be investigated are made in para 7.08, Appendix 5. As MSIRI has already investigated this process in the past it is in the best position to judge what problems require study. Ultimately, if protein can be economically recovered from the sugarcane juice, it will be necessary to conduct conventional feeding trials in order to assess the value of this protein for pig, poultry and dairy cattle rations.

Location Map



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

CONTENTS

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

Volume 2

APPENDICES 1-6B

Institutions

ACP	Lomé Convention countries of Africa, the Caribbean and the Pacific
A&M	Alcohol and Molasses Export Company Limited
ADB	African Development Bank
AMB	Agricultural Marketing Board
CCCE	Caisse Centrale pour la Cooperation Economique (Paris)
CEB	The Central Electricity Board
CSA	Commonwealth Sugar Agreement
DBM	Development Bank of Mauritius
FAO	Food and Agriculture Organisation of the United Nations
IBRD	International Bank for Reconstruction and Development (World Bank)
IDA	International Development Association (World Bank)
ISO	International Sugar Organisation
MCAF	Mauritius Cooperative Agricultural Federation Limited
MCCB	Mauritius Cooperative Central Bank Limited
MCGA	Mauritius Cane Growers Association
MM	Mauritius Molasses Limited
MMA	Mauritius Meat Authority
MMPA	Mauritius Meat Producers Association
MRC	Mauritius Research Council
MSCPA	Mauritius Sugar Cane Planters Association
MSS	The Mauritius Sugar Syndicate
MSPA	Mauritius Sugar Producers Association
MSIRI	Mauritius Sugar Industry Research Institute
ODA	Overseas Development Administration (London)
PROSI	Public Relations Office of the Sugar Industry
U of M	University of Mauritius
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organisation
UNCDF	United Nations Capital Development Fund

Units and Technical Abbreviations

bar A	measure of absolute pressure (1 bar A is effectively 1 atmosphere)
brix	weight of solids % weight of solution
BOD	biological oxygen demand
¢	cent
C	Centigrade
cif	cost, insurance and freight
COD	chemical oxygen demand
CP	crude protein
cumec	cubic metre/second
d	day
DM	dry matter
fcf	fresh, chilled and frozen
fob	free on board
gal	Imperial gallon
GL	Gay Lussac (100°GL is 100% alcohol)
GWh	Gigawatt-hour
GNP	Gross national product
g	gram
ha	hectare
hr	hour
IRR	Internal Rate of Return
kg	kilogram
kJ	kilojoule
km	kilometre
kWh	kilowatt-hour
ℓ	litre
lb	pound
m	metre
m^2	square metre
m^3	cubic metre
M	Million
ME	Metabolisable energy
MJ	megajoule
MSG	Monosodium glutamate
MW	megawatt
NCV	net calorific value
NFE	Nitrogen free extract
NPV	Net present value
Rs	Mauritius Rupees
t	tonne
tc/d	tonnes cane per day
tc/hr	tonnes cane per hour
t/ha	tonnes per hectare
y	year

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

NOTES ON EXCHANGE CONVERSIONS AND LOCAL UNITS

Exchange conversions

Costs are based on those at 1 July 1981. Exchange rates are those after the devaluation in October 1981

ie US$1 = Rs10.25
£1 = Rs19.00

The devaluation during report writing has made cost estimation particularly difficult. The foreign exchange components have been converted at the new rates. However, it is not possible to make accurate new estimates of all local costs, given that the devaluation would eventually affect some, but not all. For example, the cost of steam in the sugar factories would probably not be affected, but that of electricity would increase to the extent that imported fuel is used to generate it.

Conversion rates in the other Appendices are historical,

ie	October 1979 - October 1981	US$1 = Rs8.67
	January 1977 - September 1979	US$1 = Rs6
	Sugar crop season 1979/80 (average)	US$1 = Rs7.335

Costs before 1977 have not been converted to dollars.

(Appendix 11)

Local units

1 arpent	=	1.043 acres = 0.422 ha
1 foot	=	0.3048 metres
1 pound (lb)	=	0.4536 kg
1 gallon	=	4.546 ℓ

DIX 1

RODUCTION, PROCESSING,
DDUCTS

APPENDIX 1

THE SUGAR INDUSTRY: PRODUCTION, PROCESSING, BY-PRODUCTS

CONTENTS

CONTENTS (cont)

END TABLES

SUMMARY

1. Sugarcane is grown on 88% of the land under cultivation. Production is variable, being affected principally by cyclones. In the non-drought, non-cyclone years ("non-disaster" years) between 1972 and 1979, average sugarcane production was 6 217 000 t producing 687 000 t sugar, with sugar recovered at 11.05% cane.

2. The industry employs an average of 50 000; this is nearly 90% of employees in agriculture and about 40% of those working in the private sector. However, the work force has fallen during the 1970s, resulting in increasing mechanisation of cane loading and lengthening harvesting seasons, with a reduction in productivity.

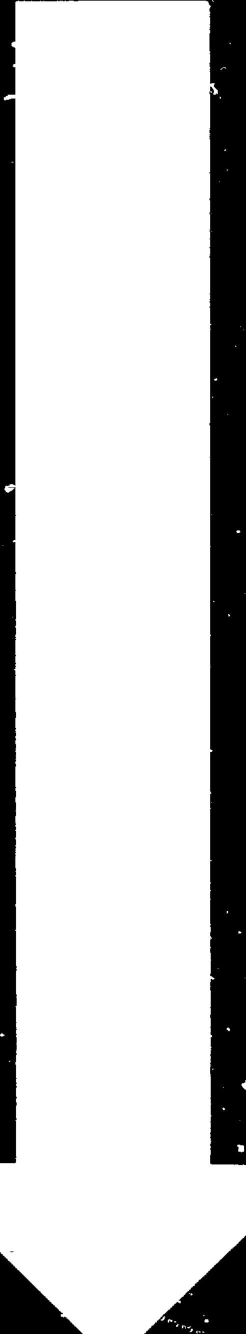
3. Average production of by-products in non-disaster years was as follows:

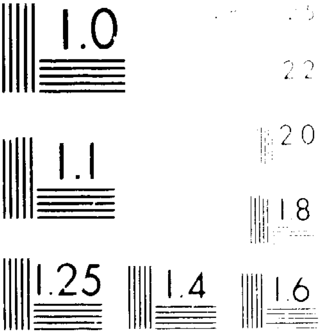
	t'000
Molasses	191
Bagasse	1 727
Cane tops	1 273
Filter mud	211

4. Sugar is marketed by The Mauritius Sugar Syndicate. Local sugar sales average 40 000 t; the remainder is exported, either under the Lomé Convention or on the world market (paras 2.08-15 Appendix 10).

5. The major part of the molasses produced (90%) is exported. Distilleries and animal feed account for the local consumption. Bagasse is used to power the sugar factories, and in addition in 1979 the industry supplied 25.7 GWh to the national electricity grid (7% of national electricity production). A condensing turbo-alternator has recently been installed at Medine, bringing saleable electricity to 47.8 GWh/y.

6. Costs of the sugar industry are not readily available. It is unlikely that, apart from 1973-74 (when Mauritius had high production available to take advantage of record world market prices) and 1979 (when the Mauritius rupee was devalued) the miller-planters as a whole made an adequate return on capital even before the payment of export duty.




1.0
2.2
2.0
1.1
1.8
1.25
1.4
1.6

7. The industry faces considerable uncertainties, particularly with labour, reorganisation, and technical problems. Estimates in this Appendix of increases in production of sugarcane, and hence of by-products, are conservative. Using as a base the non-disaster years from 1972-79, average annual cane production is expected to rise by 4%, from 6 217 000 t (1971-79) to 6 471 000 t in 1990. Production of sugar and by-products would increase proportionally.

1. CANE AND SUGAR PRODUCTION

1.01 Sugar cane is grown on about 86 170 ha 1/. This is 88% of the land under cultivation (98 000 ha) and 46% of the island's total area (186 500 ha). The areas harvested have altered very little in recent years. For several reasons, of which the island's location in a cyclone region is the most important, annual production of cane and sugar are variable (see below). In the last 10 years the best crop was 718 000 t in 1973 and the poorest was 468 000 t in 1975, a cyclone year; the average for the non-disaster years 1972-79 was 687 000 t. The current estimate for the 1981 crop is 600 000 t. Crop seasons begin in June or July and end in December.

Cane and sugar production 1971-80

	Area harvested ha	Cane production '000 t	Cane harvested t/ha	Sugar production '000 t	Sugar recovered % cane
1971 a/	79 877	5 255	66	621	11.8
1972	80 232	6 315	79	686	10.9
1973	80 949	6 242	77	718	11.5
1974	79 881	5 964	75	697	11.7
1975 b/	80 176	4 316	54	468	10.8
1976	80 863	6 402	79	690	10.8
1977	80 605	6 022	75	665	11.1
1978	80 277	5 260	78	665	10.6
1979	79 724	6 313	79	688	10.9
1980 b/	NA	4 564	-	475	10.4
1981	NA	NA	-	600 c/	NA
Average 1971-80	NA	5 765	NA	637	11.05
Average non-disaster years	80 362	6 217	77	687	11.05

a/ Drought year.
b/ Cyclone year.
c/ Estimate.

Source: MSIRI annual reports.

1.02 In 1979 (the most recent non-disaster year) the miller - planters produced 3 982 M t cane (63%) and the independent planters 2 331 M t (37%). The miller - planters harvested 44 960 ha (56%) giving a yield of 89 t/ha; the independent

1/ MSIRI. Annual report 1979.

planters yield was 67 t/ha from 34 765 ha (44%). The 32 200 independent planters mostly (96%) own their own plots. Of all the holdings, 92% harvested less than 2.1 ha (five arpents); the average plot in this size category is 0.55 ha. There are only 50 landholdings above 42 ha (100 arpents) harvested, averaging 126 ha; they represent 8% of the total land harvested.

1.03 There are 21 factories, with nominal capacities ranging from 60 tc/hr (St Felix) to 240 tc/hr (F.U.E.L.). Each factory receives cane from a legally defined area (Figure 1). Reported mechanical time efficiencies, averaging 93% in 1979, are high, eight factories average over 96%. Overall average time efficiency was 83%, the difference reflecting principally shortages of cane; this is confirmed by the comparison of the actual daily throughputs with the published capacities (79%: non-weighted average). The table below shows mechanical and overall time efficiencies from 1971 to 1980.

Mechanical and overall time efficiencies 1971-80

	Mechanical %	Overall %
1971 a/	96.5	85.0
1972	97.3	84.5
1973	96.7	84.7
1974	96.2	84.3
1975 b/	95.4	69.9
1976	95.3	79.4
1977	93.4	80.3
1978	93.0	81.3
1979	92.9	83.1
1980 a/	93.1	80.9
Average 1972-74	96.7	84.5
Average 1976-79	93.6	81.0
Averages are unweighted		

a/ Drought year.
b/ Cyclone years.

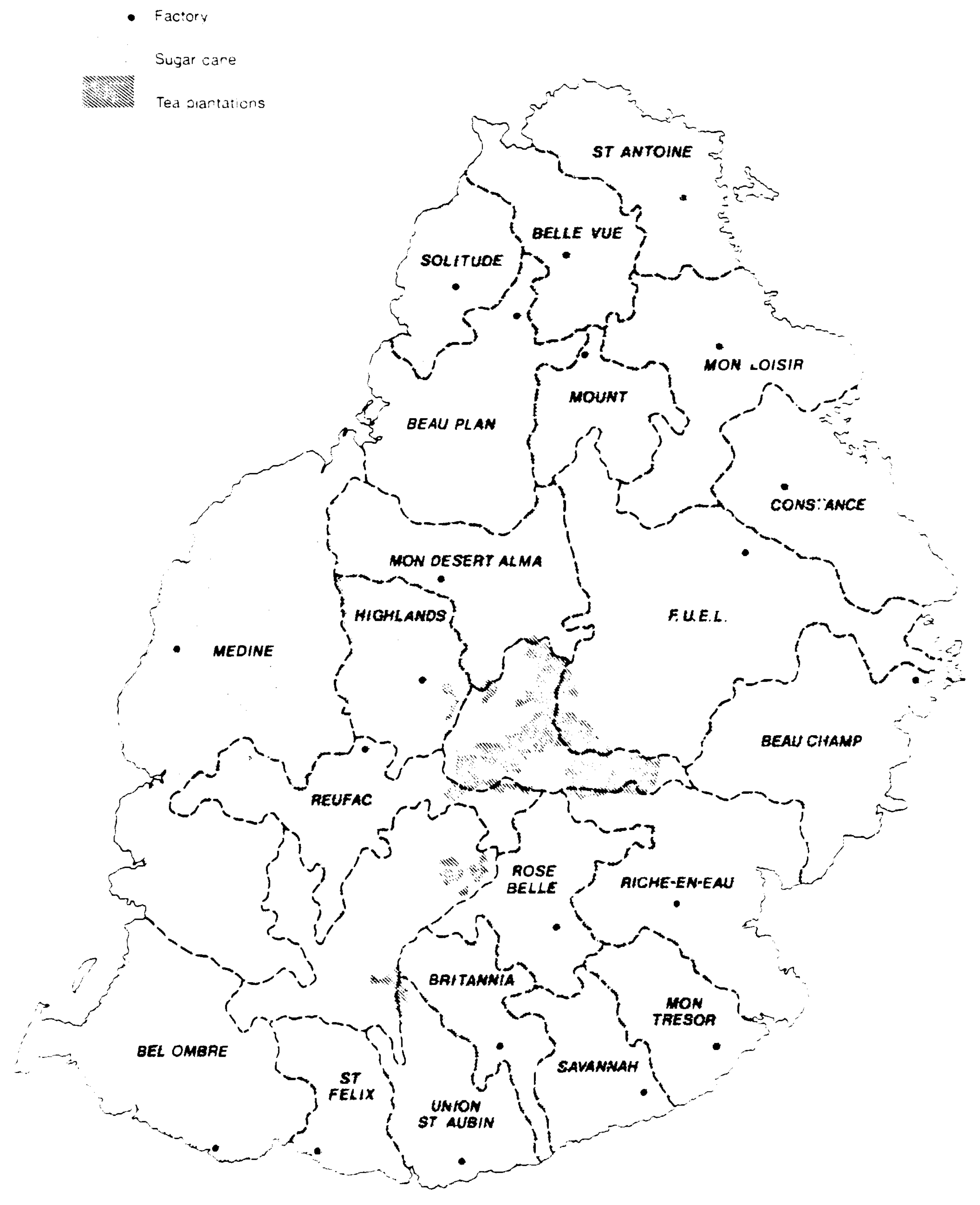
Source: MSIRI annual reports.

End Table 1 shows 1979 performances of the individual factories in sugar, and End Tables 2 and 3 in by-products.

1.04 There can be no doubt that performance in the latter part of the decade has fallen from the (albeit excellent) results obtained from 1972 to 1974. Average mechanical efficiency for 1976-79 was 3% below the earlier years, and overall time efficiency had dropped by 3.5%.

Mauritius : Designated sugarcane factory areas

Fig. 1



Source: Sugar in Mauritius, PROSI: Port Louis

BAI MAU 2

1.05 The worsening performances are reflected in falling extraction of sucrose % cane and increasing lengths of crop seasons (Figure 2: trend line correlations are -0.47 and +0.5).

Average lengths of season 1971-80

	Lengths of season (d)	Cane crushed/d
1971 a/	111	2 259
1972	132	2 280
1973	129	2 310
1974	126	2 257
1975 b/	118	1 740
1976	144	2 119
1977	137	2 099
1978	137	2 176
1979	136	2 208
1980 b/	104	2 087
Average 1971-80	127	2 154
Average non-disaster years	134	2 207
Averages of cane crushed/d are unweighted		

a/ Drought year.
b/ Cyclone year.

Source: MSIRI annual reports.

1.06 The factories produced 645 000 t of raw sugar in 1979, and 42 000 t of refined sugar. The average polarisation was 98.8°, and the total production at 96° pol was 708 000 t. The industry maintains that the longer seasons result in lower output, and this is supported by statistical evidence. There is a high negative correlation (-0.79) (non-disaster years) between length of season and extracted sucrose % cane (table in para 1.01); and a positive correlation (+0.51) between cane crushed/d and extracted sucrose % cane.

2. LABOUR

2.01 The peak number of employees in the sugar industry in the 1970-79 decade was 58 499 in September 1977. This is 90% of workers in agricultural employment, and 42% of employees in the private sector. In September 1979 the relevant figure was 52 688, of whom 7 373 (14%) were employed by the independent planters. The average output is 12.5 t sugar/worker. The statistics for the period March 1977 to September 1980 are as follows:

Sugar industry labour force 1977-80

		Total	Independent planters
1971	March	48 468	NA
	September	55 530	NA
1977	March	54 391	NA
	September	58 499	NA
1978	March	51 332	6 542
	September	53 982	7 652
1979	March	48 714	5 959
	September	52 668	7 373
1980	March	47 493	5 713

Source: Biannual digest of statistics. Central Statistics office.

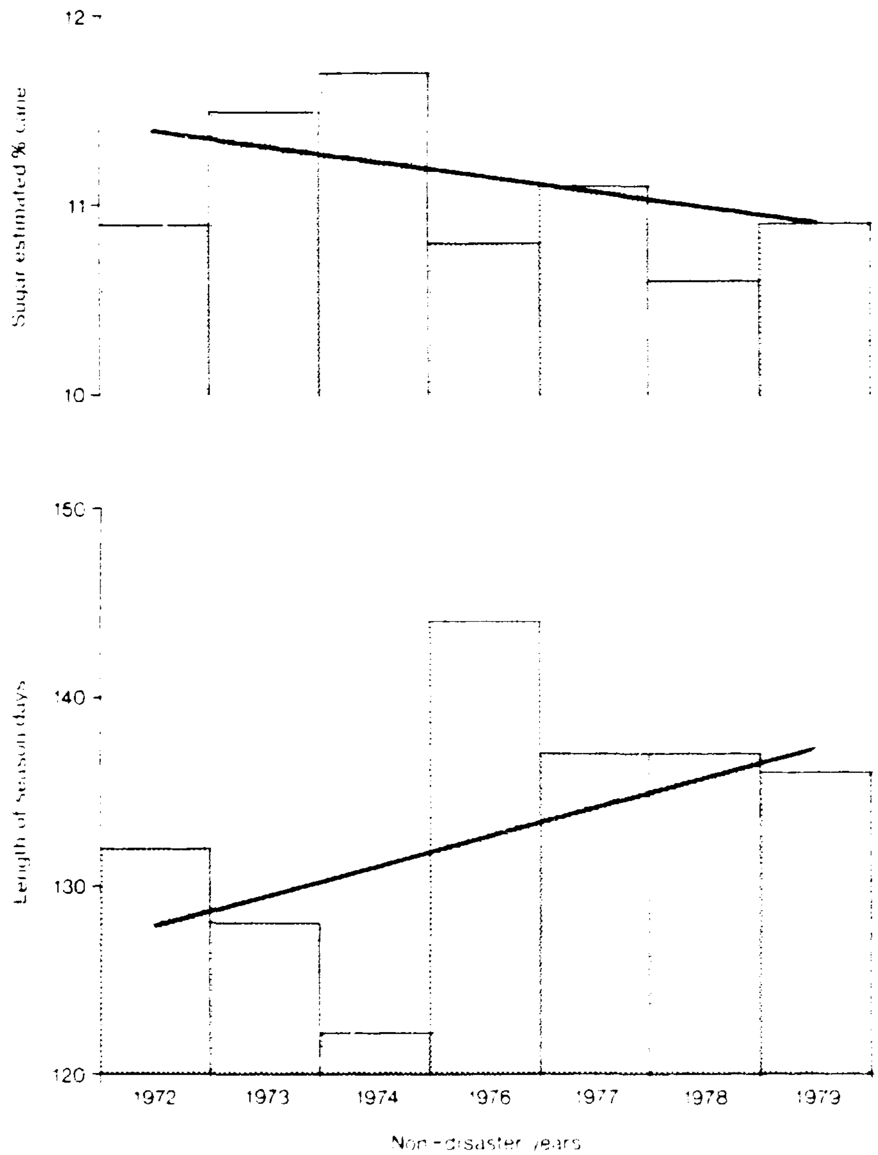
2.02 The numbers of man-days worked in miller-planter companies (ie factories and estates) has remained quite steady among monthly paid employees since 1977, while they have fallen 50% for the daily paid from 1977 to 1979. Relevant statistics are as follows:

		Man-days '000		Employees	Average man-days/ employee
		Monthly	Daily		
1977	1st half	4 344	1 027		
	2nd half	5 008	1 386		
Total		9 352	2 412		
1978	1st half	4 551	696	37 031	142
	2nd half	5 057	844	39 880	148
Total		9 608	1 540		
1979	1st half	4 785	436	35 469	147
	2nd half	4 843	781	37 486	150
Total		9 627	1 217		
1980	1st half	4 507	440		

Sources: Man-days: Biannual digest of statistics.
Employees: MSPA annual report 1979.

Mauritius : Decline in sugar extraction and increase in lengths of season, non-disaster years, 1972-79

FIG.2



2.03 Average earnings in the miller-planter companies have increased from Rs39/man-day in 1977 to Rs46 ($5.31)/man-day in 1979 for monthly paid employees. For daily paid employees the figures are Rs25/man-day in 1977 and Rs33/man-day ($3.81) in 1980. These increases are 9%/y and 16%/y respectively, or an average of 11%/y. The earnings per employee rose from Rs7 586/y in 1977 to Rs9 515 ($10.97) in 1979, an increase of 12%/y.

2.04 The most notable features of the statistics are the rise in total employees from 1970 to 1977, and the fall since 1977. There has been an intensification of efforts to increase mechanisation of field operations.

2.05 Mechanical loading of cane increased from 1.6 M t in 1978 (26% of all cane cut) to 2.2 M t in 1979 (34%). The combination of the shortage of field labour and the spread of mechanical loading (with the inevitable increase in stones, trash and other extraneous material reaching the factories) has led to the drop in the factories' overall time efficiencies.

2.06 Only about 1% of cane is mechanically harvested. Field conditions in Mauritius are not generally suitable for the operation of the present type of mechanical harvesters and it is doubtful whether they can substantially reduce the demand for cane cutter labour.

2.07 The miller-planters are required to offer year-round employment to their labour forces whose in-crop attendance is 80% or above, but this does not apply to the independent planters. Of total employees, the March 1980 figure for the miller-planters is 10% below the previous September; for the independent planters the fall is 22%. However the daily-paid employees of the miller-planters decreased by 44% over the same period.

2.08 Labour input statistics of the miller-planters are published in the MSPA annual reports. End Table 4 shows the total figures for 1979, divided between the two halves of the year (effectively out-of-crop and crop harvesting seasons). The seasonal mixes between activities in cane and sugar production are much as to be expected, but it is rather surprising that the man-days spent on food crop production are almost identical in the two half years. However the total figures conceal the different approaches of the miller-planters. Bel Ombre, Rose Belle, Beau Champ and Highlands spend more than twice the man-days in the first half (out-of-crop) than the second half; Britannia, Constance and Medine are the other way round.

2.09 "Other activities" include livestock management, but this is a small part of the total labour input. The largest livestock operation, at Medine, took 53 000 man-days, about half the total of other activities.

2.10 The total man-days spent on food crops in 1979 was 3.1% of all cultivation, and on other activities 5.5%. The miller-planters who exceeded these percentages are as follows; the complete list is provided in End Table 5.

Miller-planters most involved in food crops and other activities (% of total man-days).

	Food crops	Other activities
Medine	6.4	13.7
Solitude	5.7	a/
Beau Plan	3.7	9.7
Belle Vue	5.3	a/
St Antoine	5.8	a/
F.U.E.L.	a/	12.9
Riche-en-Eau	3.5	a/
Savannah	3.4	a/
Rose Belle	3.9	a/
Union St Aubin	4.3	8.1
(Union alone	5.6	12.6)
St Felix	3.5	5.7
Bel Ombre	a/	6.7
Highlands	4.4	a/
Average	3.1	5.5

a/ These are below average figures.

Source: Derived from MSPA 1979 annual report.

3. PRODUCTION OF BY-PRODUCTS

3.01 Production of molasses and bagasse depends primarily on the amount of cane crushed, with variations between years and between factories. End Tables 2 and 3 give production of by-products for 1979.

3.02 Molasses production (at 85° brix) as a percentage of cane has tended to rise from 1971 to 1979 from 2.75 to 3.26%, although the actual brix fell over the period (87.1° to 83.7°). In 1980 (a cyclone year), the figures were 2.95%

and 84.1°. Sugar % molasses has varied in a somewhat random fashion from 46 to 49%, being lowest in cyclone years. The table in para 3.02 gives summary data for molasses production.

Molasses production 1971-80

	Production at 85° brix		Actual	Sugars % molasses		
	% cane	Total t'000	brix °	sucrose	reducing sugars	total sugars
1971 a/	2.75	145	87.1	33.43	15.53	48.96
1972	2.84	179	86.1	31.08	18.09	49.17
1973	2.97	185	84.8	31.24	17.02	48.26
1974	2.94	175	84.6	31.39	15.82	47.21
1975 b/	2.98	129	84.5	31.09	14.96	46.03
1976	3.1	198	84.4	30.22	17.76	47.98
1977	3.19	192	83.9	30.59	17.55	48.14
1978	3.19	200	84.1	30.65	17.63	48.28
1979	3.26	206	83.7	30.91	17.53	48.44
1980 b/	2.95	135	84.1	31.45	15.10	46.55
Average	3.02	174	84.7	31.21	17.00	48.21
Average non disaster years	3.07	191	84.5	30.87	17.34	48.14

a/ Drought years.
b/ Cyclone years.

Source: MSIRI annual reports.

3.03 The average molasses produced in 1979 had a total sugars content of 48.4%. Even when expressed on an 85° brix basis the total sugars are only about 49.2%, which represents a relatively low level compared to the molasses produced in many other countries.

Molasses - analytical results 1979

	Average	Maximum	Minimum
Brix°	83.7	87.6	77.5
Gravity purity	36.9	40.4	34.0
Weight % cane @ 85° Brix	3.26	4.3	2.49

Source: MSIRI annual report 1979.

3.04 There are very large variations in analytical results between the factories in a given year. These presumably reflect differences in factory efficiencies and possibly variations in cane characteristics. As prices for molasses do not reflect fully the sugar content, it would be advantageous to any industrial user of molasses in Mauritius to select carefully the molasses having the highest sugar content.

3.05 Bagasse production from 1971 to 1980 was as follows:

Bagasse production 1971-80

	Production		Pol	Moisture	Fibre
	% cane	Total t'000	%	%	%
1971 a/	27.42	1 441	2.12	49.1	48.1
1972	26.56	1 677	1.94	49.0	48.4
1973	27.16	1 714	1.97	49.0	48.3
1974	25.44	1 580	1.99	49.1	48.2
1975 b/	29.23	962	1.98	49.5	47.8
1976	27.43	1 756	1.88	49.4	48.1
1977	28.7	1 728	1.98	49.7	47.7
1978	28.85	1 806	1.89	49.7	47.8
1979	29.0	1 831	1.96	49.6	47.8
1980 b/	30.9	1 438	1.91	49.8	47.6
Average	27.64	1 593	1.96	49.4	48.0
Average non disaster year	27.79	1 727	1.94	49.4	48.0

a/ Drought year.
b/ Cyclone years.

Source: MSIRI annual reports.

3.06 The average bagasse content of cane has risen 4% during the 1970s, from 26.56% in 1972 to 30.90% in 1980. In the cyclone years it naturally tends to be high. There are slight but steady trends for moisture % bagasse to rise and fibre content to fall. In 1979 they were 49.6% and 47.8% bagasse respectively. In the non-disaster years from 1972 to 1979, fibre % cane has risen from 12.48% to 13.66% (on the linear trend line: the correlation is +0.74); this represents the increase in trash and tops brought in by mechanical loaders.

3.07 Sugarcane tops are estimated at between 13% and 19% of green cane, and 16-26% of burnt cane 1/. On an industry average of 17%, 1.3 M t cane tops would have been available in 1979.

3.08 Filter mud production varies with cane cleanliness and process efficiency. At 3.39% cane in 1979, 214 000 t were produced.

4. COMMERCIALISATION OF SUGAR

4.01 All sugar is marketed by The Mauritius Sugar Syndicate (MSS). Local sugar sales in 1977-1980 averaged 40 000 t of which 37 000 t were refined. This consumption, about 44 kg/head, was fairly high for a developing country, but not unusual for a major sugar exporter. There are no notable exports of sugar food products. The high consumption has been facilitated by a domestic pricing policy by which all sections of the manufacturers subsidise the consumption of sugar by the population. Price increases in 1980 partly caused consumption to fall to 32 000 t. Present wholesale prices are Rs2.31/kg white ($0.23) and Rs1.71/kg raw ($0.17).

4.02 The sugar not sold on the domestic market is exported at an average polarisation of 98.5°. The principal arrangements were the Commonwealth Sugar Agreement (until 1974), and now the Lomé Convention (see Appendix 10).

4.03 In 1980 a bulk terminal was opened in Port Louis harbour. Until then all export sugar had been transported to the harbour in bags, which were bled into the holds of the bulk carriers; naturally this was expensive in terms of materials, labour and shipping charges. The terminal was financed 58% by Government and 42% by the sugar producers through levies on sugar exports in 1974 and 1975.

4.04 Export sugar is transported to the terminal at the factories' expense; some companies have their own vehicles, others sub-contract the work. Distances to the terminal vary from 13 km from Solitude to 55 km from St Felix. These are low by world standards, and no transloading of sugar is involved.

4.05 MSS handles the proceeds of sugar sold, deducting its own expenses. It also pays the statutory charges to the industry organisations and funds (see paras 3.08-3.09, Appendix 2), and the export duty. The latter varies from

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1/ Data obtained from field weighings at two sugar estates, Medine and Britannia, during the team's visit. Percentages are of cane cut.

nil on planters exporting up to 20 t to 23.625% for planters and miller-planters exporting more than 3 000 t. The latter percentage includes a 75% surcharge on the original rate of 13.5%; the surcharge was imposed in October 1979 as part of the devaluation package in order to recoup the windfall gain from the 1979 crop. It has not been removed. Proceeds from the duty since 1978 have been as follows.

Sugar export proceeds and export duty

	Gross proceeds		Export duty	
	RsM	$M	RsM	$M
1978	1 526	254	141	23.5
1979	2 044	259	281	36.5
1980	1 640	189	256	29.5

4.06 The Cane Planters and Millers Arbitration and Control Board arrange the distribution of proceeds. Currently the planters receive 74% of the proceeds of the sugar sold from their cane - a high proportion by world standards. The relevant legislation is summarised in paras 3.02-3.07, Appendix 2; a more detailed description of the Mauritius sugar markets is at paras 2.01-15 of Appendix 10.

5. COMMERCIALISATION OF MOLASSES AND BAGASSE

Molasses

5.01 Most molasses is exported. Three distilleries operate on the island, at Medine, Beau Plan and Constance (see paras 2.03-07, Appendix 6B). In 1979 their combined offtake was 15 000 t (8% of total production). Small quantities (6 000 t in 1979) are used in animal feeds. The factories own or pay for transport of molasses to one of the bulk terminals in Port Louis.

5.02 Two companies export molasses. They are Mauritius Molasses Limited (MM), owned two-thirds by United Molasses Limited (a subsidiary of Tate and Lyle) and one-third by Rogers and Company Limited: its terminal has a capacity of 24 000 t. The Alcohol and Molasses Export Company Limited (A&M) is owned by Harel Freres Limited and by some of the factories whose molasses it buys: its bulk capacity is 20 000 t.

5.03 MM sell on contract to United Molasses on a formula based on selling prices in USA and Europe. There is a guaranteed minimum price of Rs100/t ($9.75) fob stowed. A&M sell on the world market. MM are responsible for paying all independent planters. In 1981 the distillers pay Rs600/t ($59) (1980 Rs650/t ($75)). Since all the molasses distilled comes from A&M suppliers, there is an equalisation with MM at this price. Section 3, Appendix 10 contains a fuller discussion of the molasses market.

5.04 An export duty of 10% is payable on the fob proceeds of molasses. Two subsequent 10% surcharges have brought this to 12.1%.

Bagasse

5.05 Most bagasse is used for generating steam and electricity for use by the factories. Surplus bagasse has been used to generate electricity for sale to The Central Electricity Board (CEB). In 1979, the industry supplied 25.7 GWh, 7.2% of the total units generated. With the recently installed 10 MW condensing turbo-alternator at Medine the industry will supply 47.8 KWh/y.

5.06 In the few instances where bagasse has been sold, the price has been set to cover baling and transport. Universal Board (UB), the particle-board factory which operated at St Antoine from 1972 to 1978, was initially supplied with free bagasse by the factory since there was no alternative use for it at the time. St Antoine then installed a diffuser, which resulted in the reduction of surplus bagasse, so UB found itself paying about Rs100/t for baling costs and transporting bagasse from nearby factories. The estimated average cost of bagasse if UB reopens is also Rs100/t ($9.75). Its average consumption was 2 500 t/y. Its opportunity cost against coal is Rs126 ($12.31, para 7.11, Appendix 7A). Union St Aubin is supplying Bois Cheri, a tea factory, with small quantities at Rs40/t ($5.90) ex-factory for use as fuel.

6. MANUFACTURING COSTS

6.01 Costs of the sugar industry are not published in detail. Indeed the cane production costs of many independent planters are not known. During the period of the CSA, sugar prices were negotiated on the basis of the costs of a reasonably efficient producer, and for this purpose Commonwealth cane sugar industries were required to submit estimates based on asset replacement costs (since the replacement of the CSA in 1974 by the Lomé Convention prices have been set by reference to European beet sugar production costs). McKinsey and Co Inc quoted 1971 unit production costs (probably on the basis of the CSA calculations) of miller-planters as follows:

Unit production cost 1971

Rs/t sugar		Capital cost	
		Historical Rs/t	Replacement Rs/t
Growing		344	368
Milling		143	161
Total		487	529
	$/t	81	88

Source: McKinsey and Company Inc.

In 1971 the average price received was Rs 647/t ($108).

6.02 The 1979/80 report of MSS observes that the August 1980 domestic prices of raw sugar (Rs1 250/t) and white sugar (Rs1 850/t: $144 and $213) pay for less than two-thirds of the industry's current cost of sugar production. Given the exceptionally large refining margin, one cannot put the cost of production more precisely than in the range Rs2 050-2 530/t raw sugar ($236-292). In 1979 the average ex-MSS proceeds were Rs2 146/t ($293); export duty was Rs407/t ($55).

6.03 MSPA published the following figures in July 1981 relating to the miller-planters for the 1980 crop:

Miller-planters' costs 1980

Production	475 494 t Total costs Rs M	Rs/t
Receipts	1 557	3 274
Wages and salaries	629	1 323
Materials	298	627
Depreciation (at replacement costs)	254	534
Insurances + other costs paid to government organisations (including water and electricity)	262	551
Export duty	234	492
Other taxes	44	92
	1 721	3 619
Net deficit	164	345
Capital invested	2 000	4 206
	$M	$/t
Receipts	180	354
Costs	199	417
Net deficit	19	63
Capital invested	231	485

6.04 Clearly 1980, a cyclone year, was not likely to be highly profitable for the sugar companies. Before export duty, the return on capital invested would have been only 3.5%. In 1977 to 1979, three non-disaster years, the figures were as follows:

Miller-planters' profits and losses before paying export duty

	Net profits (losses) a/		Export duty b/		Gross profits		Return on capital % c/
	RsM	$M	RsM	$M	RsM	$M	
1977	(45)	(7)	91	15	46	8	4.6
1978	(72)	(12)	98	16	26	4	2.4
1979 d/	34	5	195	27	229	32	18.4

a/ Source MSPA 27 July 1981.
b/ Sources 1978, 1979 - MSPA 27 July 1981.
c/ Capital taken as Rs2 000 M at 1980 prices, adjusted for inflation.
d/ 1979 - devaluation of the Mauritius rupee in October.

6.05 MSPA estimated that the miller-planters' collective deficit in 1981 would be Rs305 M ($30 M) and that the export duty payable by them will be Rs292 M ($28 M). This is a net deficit of Rs17 M ($1.6 M). The figures were based on estimated production of 620 000 t; since current estimates are now 600 000 t, the deficits will probably be larger and the duty payments smaller. (Dollar figures in this paragraph are at post-1981 devaluation rates).

7. THE FUTURE OF THE SUGAR INDUSTRY

7.01 The economy of Mauritius depends critically on its sugar industry. The figures provided by MSPA point to a difficult future. Statements by all bodies involved in the industry tend to be pessimistic. The industry-wide position is probably not as serious as MSPA states, since costs of independent planters are likely to be lower than those of miller-planters. However, if production costs are to be reduced, certain fundamental problems need to be faced. Of these the principal ones are:

- labour;
- reorganisation;
- technical problems.

Labour

7.02 Given its importance in the economy of Mauritius, the sugar industry has always been the largest employer. As in most countries with GNPs well above the poverty line, the interests of employers, employees and governments have tended to move in totally different directions. In Mauritius one result has been overmanning in the factories (albeit at quite low wage rates - and with the spin-off of an industry whose technical performance is exceeded by only three or four countries in the world). Other results have been a reduction in the labour force in cane harvesting, which is socially unattractive (although by no means to the extent as in some of the less developed tropical countries, where migrant labour is often used), and a drain of Mauritian factory artisans to producers in other countries.

7.03 The different interests of the participants have led to periods of labour unrest. These were particularly prevalent in the harbour of Port Louis before the bulk terminal was opened however unrest and disruption in the industry itself in 1979 (vividly described in the 1979 MSPA annual report) was by no means unusual, and although there was greater community of purpose later in 1979, the present management/labour infrastructure is hardly conducive to stability.

Reorganisation

7.04 In the industry itself productivity has been falling. In 1979 the 21 factories in Mauritius produced on average 241 t sugar/d on 136 crushing days. In 1971 they produced 266 t/d each in 111 crushing days.

7.05 It is unlikely that a new factory producing less than 50 000 t sugar/y and working on less than 220 days/y would be described as a worthwhile investment opportunity in present-day terms. By this rule of thumb, only two Mauritian factories would be viable in terms of annual output, and seven on daily capacity.

7.06 The principal limiting factor is the area of land in which it is economically worthwhile to grow sugarcane. Availability of water for irrigation is also a constraint in the dry areas. The area harvested did not change materially between 1971 and 1979.

7.07 In the circumstances it must be apparent (and indeed is within the industry) that with no likelihood of any major increase in productive cane land, the number of factories is in excess of needs. The savings that would result from reducing the number of factories to, say (as the industry does) 11, would undoubtedly outweigh the additional transport costs. This will be politically difficult, given the interests of:

a) the factories that would close;

b) the independent planters (who ought to consider themselves sufficiently well protected - see Appendix 2);

c) the labour unions, whose members in the factories would find themselves at the receiving end of most of the cuts in production costs.

7.08 Two factories (Solitude and Reufac) have recently applied to the Minister of Agriculture to close; they are required to show sufficient reason by law. Both were apparently making large losses. The Minister referred their applications to the courts on the grounds that neither had proved an adequate economic case for closing. The courts dismissed the referrals. The law has since been amended to give the Minister absolute discretion and the two factories must continue operations, at least through the 1981 crop season.

Technical problems

7.09 The increasing number of crushing days during the crop season has been cited in industry circles as an important cause of falling production; it has arisen mainly from labour difficulties, but also from cash shortages (with two cyclone years in six, and the export duty) which have caused maintenance expenditure to fall below optimum levels.

7.10 Cane yields per hectare among the miller-planters are reasonable by world standards. Nor need the independent planters feel ashamed by comparison with their overseas rivals. Higher average yields may be achieved firstly by improved irrigation availability and techniques, and secondly by progressively destoning the fields.

7.11 The area of cane under irrigation is at present 20% of the total. Under new schemes, of which the Northern Plains area is the most significant another 2% will come under command by the end of 1982. However, water is a constraint, and the water lost by evapotranspiration is seldom fully replaced by irrigation and rain water both in plants and ratoons.

7.12 The efficiencies of the irrigation systems used may be improved. One third of the land, presently under surface irrigation, might be converted to sprinkler, with a 40% increase in efficiency of water use. Sprinkler systems, however, are expensive to instal and operate, both in energy and financial terms.

7.13 The other two thirds of the irrigated land are already under sprinklers. Recent developments in drip irrigation can offer up to a further 40% increase in efficiency over sprinkler. It is in commercial use in Hawaii, and experiments with it are being carried out by the Mauritius Sugar Industry Research Institute (MSIRI) and at two sugar estates. It is fairly cheap to instal and operate. However management control will need to be at least as effective as with sprinkler. The change from sprinkler to drip will be slow, given firstly the necessary alterations to field-edge technology and secondly the present industry-wide investment in advanced sprinkler systems.

7.14 A large proportion of the present cane land (about 5% of the surface) is covered by boulders of volcanic or plutonic origin and in many fields these have been heaped into rows or pyramids. The removal of these boulders is both expensive and energy intensive: in many fields it would not be economic. Destoning is being done, usually before replanting, not only to increase the area under cane but also to facilitate subsequent mechanical operations. By 1990, destoning may be expected to add 1% to land under cane, and hence to cane production.

7.15 Mechanisation of cane loading has (as in other countries) led to an increase in the amounts of earth and stones that are brought to the factories with the cane. This raises production costs in the factories, and is often the cause of stoppages. Good training and careful operation are important, and progressive destoning will help, but it is unfortunately true that increasing field mechanisation will create problems for the factories.

7.16 The sucrose content of the cane has risen on average (1974-79) from 11.7% at the beginning of the crop to 12.7% at the end (Figure 3). The low sucrose content at the beginning of the season might be alleviated by the introduction of new varieties from overseas, and research is being done on early maturing varieties. Treatment with cane ripeners in April and May is having some success; in 1979 an average increase of about 1.5% recoverable sucrose in cane was obtained over 2 000 ha.

7.17 Industry-wide research work in Mauritius is conducted by MSIRI whose worldwide reputation is considerable. It is financed by a cess of Rs12.6 M (1979 $1.5 M) or Rs18/t sugar ($2) produced. Its 1981 budget is Rs16 M ($1.85 M), but the institute is being forced to cut back on some of its activities. MSIRI is discussed in more detail in Appendix 2.

7.18 For an industry with a centralised and well organised research facility, the amount of cash available for spending on programmes which must have a vital impact on its future is rather low. Further it is unreasonable to expect outstanding results from MSIRI at a time when financial cutbacks are taking place. MSIRI affects the present study of by-products not only through the quantities available (and hence the industry's revenue) but also with its work on uses of individual by-products. A stable and adequate financial arrangement for MSIRI is therefore essential not only to the sugar industry but also to the economy of Mauritius.

Projected production

7.19 The average production of sugar for 1972-79 (excluding 1975, a cyclone year) 687 000 t/y, from 6 217 000 t cane, at 11.05% sucrose recovered will serve as baseline figures. The principal sources of possible improvements are:

a) to continue destoning the land, with a corresponding increase in area under cane; an estimate of a further 1% of cane production by 1990 has been made;

b) to upgrade irrigation systems; the impact is impossible to quantify without detailed investigation. The maximum assumption is one-third of the present cane production on irrigated land, or about 24 000 t sugar. A more reasonable estimate, made solely for the purpose of this study, is 15 000 t. The changeover would be slow, given the present investment in sprinkler equipment and the early state of development of drip, and the full increase would not occur before 1990; and

c) to succeed in improving factory performance, and in ending the seasons before the onset of bad weather; this would lead to an increase of the order of 10 000 t sugar/y, which would be partly offset by the effect of increased mechanisation of cane loading.

7.20 On the basis of these three factors alone, estimates of average production in non-cyclone years are made as follows:

Projected average production of sugar and by-products 1985 and 1990 t'000

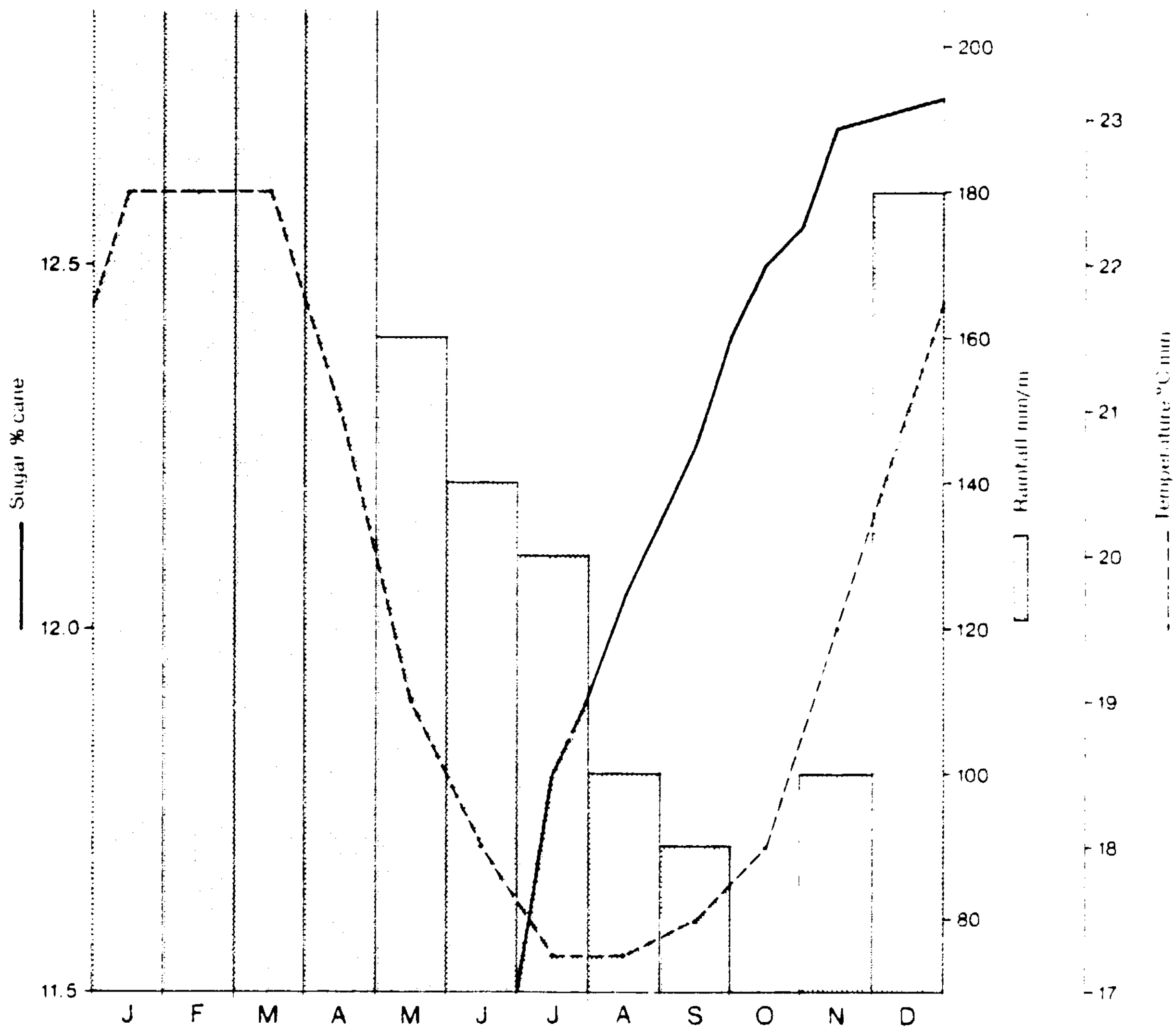
		Base a/	1985	1990
Cane milled		6 217	6 330	6 471
Sugar	11.05% cane	687	699	715
Cane tops	17% cane cut	1 273	1 295	1 325
Molasses	3.07% cane	191	194	199
Bagasse	27.79% cane	1 727	1 759	1 798
Filter mud	3.4% cane	211	215	220

a/ Non-disaster years 1972-79.

This represents an increase of 4% in cane production between now and 1990. This can be handled by existing factory capacity at the overall operating efficiencies attained in the early 1970s. If the estimate proves to be excessively pessimistic, consideration might be given to starting the crop slightly earlier (the onset of rains at the end of the season precludes a later finish); this would probably become necessary between 1990 and 2000 as improvements in irrigation efficiencies accelerate.

Mauritius : Sugar yields % cane, with climatic data

FIG.3



Source: MSIRI (1979) Annual report

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END TABLES

Mauritius: miller-planter production statistics 1979 - sugar

End Table 1

	Number of crushing days	Overall time efficiency %	Mechanical time efficiency %	Cane crushed t'000			Crushing tc/hr		Sugar produced t	Sugar produced % cane
				Miller-planters	Planters	Total	Actual	Nominal		
Medine	123	84.7	89.3	285	141	426	170	170	50 243	11.8
Solitude	123	89.4	95.9	51	167	218	82	80	22 590	10.4
Beau Plan	123	84.8	98.2	74	148	222	80	90	24 797	11.2
Mount	128	90.8	94.2	160	76	236	85	80	26 397	11.2
Belle Vue	140	77.2	87.7	146	173	319	123	125	34 904	10.9
St Antoine	128	84.2	92.9	106	143	249	96	100	27 718	11.1
Mon Loisir	124	81.1	96.5	189	121	310	126	125	34 376	11.1
Constance	144	78.4	91.3	173	123	296	109	110	31 094	10.5
F.U.E.L.	156	82.2	88.5	450	299	749	234	240	80 883	10.6
Beau Champ	136	85.3	94.9	305	158	463	166	160	46 553	10.1
Riche-en-Eau	143	74.6	96.5	258	46	304	119	120	32 153	10.6
Mon Tresor	140	82.8	95.6	238	44	282	102	100	31 151	11.0
Savannah	143	87.9	93.2	230	91	321	107	110	34 475	10.7
Rose Belle	141	77.9	90.4	166	77	243	92	90	25 051	10.3
Britannia	128	86.3	96.9	157	73	230	87	90	25 359	11.0
Union St Aubin	153	74.2	78.5	283	4	287	105	110	30 421	10.6
St Felix	132	87.5	97.1	62	93	155	56	60	16 671	10.8
Bel Ombre	139	80.1	95.2	125	65	190	71	70	21 389	11.3
Reufac	124	86.7	92.6	131	72	203	79	80	23 019	11.2
Highlands	124	81.7	96.8	142	86	228	95	100	26 350	11.6
Mon Desert Alma	140	80.9	94.7	250	132	382	141	140	42 743	11.2
Total and Averages	136	83.1	92.9	3 981	2 332	6 313	111	112	688 357	10.9

Source: MSIRI annual report, 1979.

APPENDIX 1

Mauritius: miller-planter production statistics 1979 - molasses

End Table 2

	Molasses produced t 85% brix	Molasses % cane @ 85% brix	Brix°	Sucrose %	Reducing sugars %	Total sugars %	Gravity purity
Medine	13 928	3.27	85.8	31.54	18.18	49.72	36.8
Solitude	9 052	4.16	78.8	29.14	16.93	46.07	37.0
Beau Plan	8 664	3.90	85.7	29.15	20.67	49.82	34.0
Mount	7 973	3.38	84.0	28.70	18.50	47.20	34.2
Belle Vue	13 160	4.13	80.2	32.37	13.74	46.11	40.4
St Antoine	10 723	4.30	84.8	32.96	17.64	50.60	38.9
Mon Loisir	12 180	3.93	85.2	30.30	19.15	49.45	35.6
Constance	10 905	3.69	82.7	30.73	19.23	49.96	37.2
F.U.E.L.	22 687	3.03	83.0	29.40	18.40	47.80	35.4
Beau Champ	14 630	3.16	84.0	32.00	21.30	53.30	38.1
Riche-en-Eau	9 343	3.07	80.6	30.37	16.29	46.66	37.7
Mon Tresor	8 298	2.94	87.1	32.16	17.58	49.74	36.9
Savannah	9 577	2.98	85.7	32.64	14.75	47.39	38.1
Rose Belle	6 050	2.49	85.7	32.48	17.01	49.49	37.9
Britannia	6 480	2.82	84.2	29.93	17.72	47.65	35.5
Union St Aubin	7 605	2.72	87.6	31.80	15.85	47.65	36.3
St Felix	5 088	3.29	87.0	33.34	20.01	53.35	38.3
Bel Ombre	5 995	3.16	77.5	29.47	13.98	43.45	38.0
Reufac	6 402	3.14	81.1	3.041	14.89	45.30	37.5
Highlands	6 647	2.91	84.6	30.90	15.82	46.72	36.5
Mon Desert Alma	10 429	2.73	84.7	30.63	16.81	47.44	36.2
	206 016	3.26	83.7	30.91	17.53	48.44	36.9

Source: MSIRI annual report, 1979.

Mauritius: miller-planter production statistics 1979 - bagasse and filter mud

End Table 3

	Bagasse produced t	Bagasse % cane	Pol % bagasse	Moisture % bagasse	Fibre % bagasse	Filter mud produced	Filter mud % cane	Pol % mud
Medine	125 223	29.4	2.24	49.9	47.0	14 567	3.42	0.82
Solitude	69 198	31.8	2.05	47.8	49.3	6 245	2.87	0.98
Beau Plan	67 315	30.3	1.30	49.1	49.1	10 242	4.61	1.70
Mount	70 526	29.9	1.86	48.1	49.4	8 067	3.42	1.28
Belle Vue	99 418	31.2	1.90	48.7	48.7	10 930	3.45	0.90
St Antoine	83 791	33.6	1.77	51.2	46.4	5 212	2.09	1.86
Mon Loisir	93 290	30.1	1.56	50.0	47.9	9 050	2.92	0.80
Constance	91 318	30.9	1.88	46.8	50.6	10 166	3.44	0.58
F.U.E.L.	204 403	27.3	2.19	40.3	46.8	22 911	3.06	0.63
Beau Champ	137 044	29.6	1.98	50.2	47.2	15 788	3.41	0.61
Riche-en-Eau	92 211	30.3	1.89	49.8	47.6	14 455	4.75	1.69
Mon Tresor	87 215	30.9	2.10	49.5	47.8	8 157	2.89	0.86
Savannah	86 769	27.0	2.30	49.5	47.5	6 106	1.90	1.08
Rose Belle	70 709	29.1	2.32	50.6	46.[illegible]	10 789	4.44	1.84
Britannia	58 362	25.4	1.74	49.0	48.7	7 720	3.36	1.88
Union St Aubin	78 621	27.4	2.32	50.0	46.0	9 785	3.41	0.71
St Felix	41 752	27.0	2.05	48.9	48.3	4 546	2.94	1.57
Bel Ombre	56 159	29.6	2.14	49.9	47.4	5 521	2.91	2.44
Reufac	55 453	27.2	2.12	48.7	47.2	7 808	3.83	2.56
Highlands	61 674	27.0	1.31	50.7	47.5	8 132	3.56	1.85
Mon Desert Alma	101 233	26.5	1.69	48.9	48.8	17 763	4.65	1.81
	1 831 684	29.0	1.96	49.6	47.8	213 960	3.39	1.26

Source: MSIRI annual report, 1979.

APPENDIX 1

Mauritius: Miller-planter labour inputs 1979 End Table 4

	January - June	July - December
Agriculture (sugar)		
Plantation	445	183
Cleaning	1 272	664
Irrigation	105	118
Trashing	410	159
Cutting and loading	98	1 602
Gleaning and watching	80	166
Relieving straw	20	382
Fertiliser application	30	84
Earthing up	40	40
Repairs to infrastructure	183	57
Other agricultural	450	327
	3 133	3 782
Factory		
Processing	25	437
Sundries	551	227
	576	664
Other		
Mechanical transport	408	511
Non-recurrent	140	65
Food crops	115	120
Other activities	273	141
General and management	345	326
	1 281	1 163
	4 990	5 609

Source: MSPA annual report, 1979.

Mauritius: man-days spent on other activities and food crops 1979 End Table 5

Miller-planters	Sundries		Total cultivation + sundries	% food crops	% other activities
	Other activities	Food crops			
Medine	104	18	807	2.2	12.9
Solitude	1	6	105	5.7	1.0
Beau Plan	13	5	134	3.7	9.7
Mount	7	1	242	0.4	2.9
Belle Vue	-	12	225	5.3	-
St Antoine	6	13	225	5.8	2.7
Mon Loisir	12	7	351	2.0	3.4
Constance	7	5	284	1.8	2.5
F.U.E.L.	117	55	853	6.4	13.7
Beau Champ	18	4	576	0.7	3.1
Riche-en-Eau	19	16	460	3.5	4.1
Mon Tresor	10	8	416	1.9	2.4
Savannah	11	13	385	3.4	2.9
Rose Belle	1	15	383	3.9	0.3
Britannia	2	5	467	1.1	0.4
Union St Aubin	28	15	347	4.3 a/	8.1 a/
St Felix	8	5	141	3.5	5.7
Bel Ombre	19	6	283	2.1	6.7
Highlands	6	13	294	4.4	2.0
Mon Desert Alma	21	11	568	1.9	3.7
Total	412	233	7 548	3.1	5.5
		a/	Union alone	5.6	12.6

Source: MSPA annual report, 1979.

APPENDIX 1

APPENDIX 1

APPENDIX 2 INSTITUTIONS RELEVANT TO THE STUDY

CONTENTS

CONTENTS (cont)

1. INTRODUCTION

1.01 The following pages review the major institutions relevant to the study and their principal activities. All dollar conversions of 1979 rupee figures are at the rate following the 1979 devaluation.

2. SUGAR PRODUCERS ASSOCIATIONS

The Mauritius Sugar Producers Association (MSPA)

2.01 This association represents the 21 miller-planters and two large estates without factories. It deals mainly with their problems in respect of employment and represents them in matters of general interest. In that capacity, MSPA negotiates with Government, trade unions and wage councils on all questions of labour legislation and conditions of employment.

The Mauritius Cane Growers Association (MCGA)

2.02 This association represents larger planters who individually produce more than 1 000 tc/y. It groups about 100 producers who own about 8 500 ha and produce about 600 000 m tc/y, or about 65 000 t of sugar. MCGA carries out for its members approximately the same functions as the Mauritius Sugar Producers' Association.

The Mauritius Sugar Cane Planters Association (MSCPA)

2.03 MSCPA comprises 150 members producing 100 000 t cane/y. It represents them in the same way as the MCGA does the larger growers.

The Mauritius Cooperative Agricultural Federation Limited (MCAF)

2.04 This is an association of small owner-planters grouped into some 400 cooperative societies, which include about 80% of the 30 000 owner-planters. MCAF was established in 1913. Its development was slow until after 1948, when the Mauritius Cooperative Central Bank Limited was founded. The new bank gave a strong impetus to further development of cooperative societies. In 1943 43% of all independent owner-planters' cane was supplied through cooperative credit societies.

3. SUGAR INDUSTRY ORGANISATIONS

The Mauritius Chamber of Agriculture

3.01 The Chamber of Agriculture was founded in 1853 and includes among its members the various agricultural producer groups, as well as representatives of commercial firms, banks and other institutions. The Chamber is the leading private sector body in agriculture, and has several roles: firstly, it provides a top level forum in which issues affecting agriculture and agricultural industries are discussed, problems resolved, policies established and changes initiated; secondly, it brings to the notice of the Government the representations made by the various sectors of the industry; thirdly, it provides a link between the sugar industry of Mauritius and overseas institutions of interest to the industry; fourthly, it collects and publishes agricultural and sugar statistics, and maintains industry-wide statistics. A statistical bulletin is published in the Chamber's annual report and includes all relevant data concerning production, exports, prices, field and factory results for sugar and other agricultural industries; and finally, it fulfils a public relations function for the sugar industry both inside and outside the country. This function is performed through a special public relations office (PROSI) which the Chamber created in 1968. The office operates as an independent unit, and publishes a well-informed monthly bulletin in French and English, with short articles on sugar-related matters of all kinds, labour relations, national economic policy, and items of general interest to many Mauritians.

Cane Planters and Millers Arbitration and Control Board

3.02 The Board is a statutory body set up in 1939. Its main functions are to arbitrate in disputes arising between millers and planters regarding the sale of cane, to determine the boundaries of the factory area for each factory and to assess the quantity of sugar which planters receive in payment for their crushed cane. All the functions which the Arbitration and Control Board performs are intended to supervise the equitability of the revenue sharing between the planters and the millers. The distribution of the proceeds are defined by the Cane Planters and Millers Arbitration and Control Board Act, 1973, as amended in 1976.

3.03 Planters are paid by the mills in kind, on the basis of revenue sharing formulae which provide that planters are entitled in the first instance to 74% of the sugar extracted from their cane, while mills are allowed to retain up to 26% of the sugar from the cane they process.

The planters are entitled to 74% of the proceeds from the molasses and all the scum (filter mud) produced. They are also entitled to 100% of proceeds of their bagasse not used in the generation of energy for sugar production. The planters receive their share of sugar on the basis of the actual extraction rate of the factory to which they sell their cane, or on the average efficiency of all sugar factories in Mauritius - whichever is the higher. As part of its duties, the Control Board is actively involved in sampling cane weights, chemical testing of the cane, the extracted juice, the imbibition water, the bagasse, the molasses and the filter mud.

3.04 The Board determines the cane transport rate chargeable to the planters; the millers pay any transport costs in excess of four miles (6.4 km).

3.05 Under the Act, the miller may not close his factory except with the authorisation of the Minister of Agriculture and subject to any conditions he may make. The Minister may authorise a closure:

a) "if he is satisfied that there are good grounds for doing so; and

b) after appointing a board of enquiry to investigate and report ....." (Section 24(2) of the Act).

The board "shall give consideration to all the circumstances it considers proper, including the economic functioning of the sugar industry with due regard to the employment of labour and the disposal of cane in the factory area" (Section 24(3) of the Act). No factories have closed since the passage of the Act, but two have recently submitted notices to the Minister.

3.06 The Board consists of a Chairman, a representative of the Ministry of Agriculture, two representatives of millers, one representative of planters producing cane on more than 30 arpents (12.7 ha) and one representative of small planters producing cane on less than 30 arpents, one representative of cane planters who are members of credit cooperative societies, and one independent member. The board may coopt members with the approval of the Ministry of Agriculture. Both the Chairman and other members of the Board are appointed by the Minister of Agriculture. All Board questions are decided by simple majority, with the Chairman having a casting vote.

3.07 The board is financed by a special export duty payable by MSS via the Consolidated Fund. In 1979 the rates were Rs13.57/t ($1.57) for planters and miller-planters, and Rs0.21/t ($0.02) for millers. The duty amounted to Rs8.9 M ($1 M).

The Mauritius Sugar Syndicate (MSS)

3.08 The Mauritius Sugar Syndicate, which was founded in 1919, is the sole sugar marketing organisation in Mauritius. Its main objective and responsibility is the marketing of all the sugar delivered for sale by the producers, and distributing the proceeds of such sale as calculated by the Control Board. MSS's main tasks include:

a) entering into contracts of sale with purchasers;

b) chartering vessels for export of sugar;

c) establishing contractual agreements for storage;

d) making advance payments to producers through their brokers, as and when their sugar arrives in Port Louis;

e) working out the average producer price per tonne of sugar (after all taxes, levies, administration and other expenses have been paid). This average net price varies according to the categorisation of the producers for export duty payable and for the MSIRI cess: the premium payable by each producer to the Sugar Insurance Fund Board is then deducted;

f) effecting the final distribution of revenue to each producer or his representative through his respective broker; and

g) operating a laboratory which examines sugar samples arriving at and leaving the terminal, in order to analyse their polarisation, moisture, filterability, starch content, ash, colour, grain size etc. Results of the tests are communicated to the Cane Planters and Millers Arbitration and Control Board which makes use of them for computation of the final weight of sugar accruing to each planter and miller.

Statements of account for the years 1978/79 to 1980/81 appear in End Table 1.

3.09 The London sugar brokers and their representatives in Mauritius, the shippers, act as agents between MSS and the refiners who buy Mauritian sugar. All bids for sale of sugar are dealt with by MSS through them. Brokers are also responsible for drawing up contracts, preparing accounts of sale, and keeping MSS informed of world sugar news by means of cables, telex and daily, weekly and monthly reports.

Mauritius Sugar Terminal Corporation

3.10 The Mauritius Sugar Terminal Corporation was formed by an Act of Parliament in 1979. The estimated construction cost of the terminal, Rs300 M ($34.6 M), was financed by equity, with government providing Rs173.5 M (58%-$20 M) and the sugar producers Rs126.5 M (42%-$14.6 M) by means of levies on exported sugar of Rs100/t ($16.60) in 1974 and 1975. An overrun of Rs30 M ($3.5 M) was financed partly by loans and partly out of internal resources. The board consists of an independent Chairman and 16 members, appointed as follows:

Government ministries:
- Prime Minister's office
- Finance
- Agriculture and Natural Resources and the Environment
- Economic Planning and Development
- Commerce and Industry
- Communications
- Labour

Director General of the Marine Authority
Planters organisations (3)
Millers
Miller-planters
MSS
Employees (2)

3.11 The bulk terminal opened at the beginning of the 1980 crop season; it has a total capacity of 350 000 t, and a loading capacity of 1 400 t/hr, making it the third largest in the world.

4. SUGAR INDUSTRY FUNDS

Sugar Insurance Fund Board

4.01 The Fund was established in 1946 as the Cyclone and Drought Insurance Board, and operates now under the provisions of the Sugar Insurance Fund Act of 1974 as subsequently amended. The main objective of the Fund is to insure the island's sugar production against losses due to cyclones, drought and excessive rainfall. The Fund also provides compulsory insurance for the loss of cane by fire. By equalising producers' earnings through paying them compensation for losses in bad years and transferring part of their income into savings in good years, the Fund has become one of the major stabilising instruments of the Mauritian economy.

4.02 The Fund is administered by a Board consisting of the Financial Secretary who is Chairman, the Permanent Secretary of the Ministry of Agriculture, the Director of the Ministry of Economic Planning, the General Manager of the Control Board, a representative of the Chamber of Agriculture, two representatives of organised planters, one representative of non-organised planters, a representative of the millers, and a member nominated by the Minister of Finance.

4.03 Sugar insurance in Mauritius is compulsory. The amount of insured sugar for planters is determined as 74% of the average of the 3 best of the preceding 12 crop years. In such circumstances, the Fund makes an assessment of the expected yield on the basis of the best available information. Millers, on the other hand, have to insure the remaining 26% of the planters' sugar in their respective factory areas as well as 100% of sugar grown on their own land.

4.04 The insurance scheme provides for the establishment of a complicated ranking for each insured in order to determine a corresponding premium rate. The ranking is based on a formula which determines successive alterations as a result of the claims history of each planter, taking into account his compensation-premium ratio for each year. The ranking determines the rate of premium payable, the first lost percentage of insurable sugar to be borne by the planter, and the percentage of shortfall to be compensated.

4.05 The premiums are collected by MSS (see paras 3.08-3.09); in 1979 they amounted to Rs104 M ($14 M). Total compensation in 1979 was Rs35 M ($5 M). In 1978 the comparable figures were Rs90 M and Rs51 M. Total assets at 31 May 1979 were Rs308 M ($42 M).

The Sugar Industry Development Fund

4.06 The Sugar Industry Development Fund was created in 1974, replacing the Sugar Industry Rehabilitation Fund founded in 1948. It is financed by a compulsory duty on exports. There are three associates: the Central Fund; the Sugar Millers Development Fund; and the Sugar Planters Development Fund. All three funds are administered by committees appointed by the Minister of Agriculture with one member appointed by the Minister of Finance. The rate of the duty is determined annually by the Minister after consultation with the Development Fund Committee, and the duty is paid to the Fund by MSS. In 1979 that duty was Rs22.7/t ($2.62), yielding Rs15.7 M ($1.8 M). The objectives of the Central Fund appropriations are to finance projects which will increase the productivity of small planters, and projects planned to increase cane production generally. The money not spent by the Central Fund is appropriated to the Millers Fund and the Planters Fund in proportion to the sugar accruing to millers and planters and to their tenant-planters, respectively, in any crop year.

4.07 Money accruing to the Millers Fund is designated for construction, renovation, enlargement or re-equipping industrial buildings, and for the purchase, repair and modificiation of rolling stock or mechanical field equipment used for purposes connected with the sugar industry.

4.08 Money accruing to the Planters Fund may finance expenditures that planters incur for the replacement, restoration or improvement of their buildings, mechanical field equipment and rolling stock, and for agricultural work performed on their land by mechanical field equipment owned or supplied by the Fund.

The Sugar Planters Mechanical Pool Corporation

4.09 This institution is a subsidiary of the Planters Fund. The Pool was established to provide mechanical field equipment and rolling stock to planters and their tenants who cannot afford the necessary investment for their own equipment. The major activity in which the mechanical pool engages is destoning and derocking of cane fields.

The Sugar Industry Labour Welfare Fund

4.10 This Fund was created in 1948. It is administered by a Managing Committee comprising 18 members appointed by the Minister of Social Security. The main source of income of the Fund is a duty on sugar exported from Mauritius. In the 1979 crop that duty was Rs9.1/t ($1.04) yielding Rs6.3 M ($726 000). Other sources of income are interest earned by the Fund's own investments and loans, rentals of property, and contributions of the Port and Harbour Employers Association. The main objectives of the Fund are to provide loans to the workers of the sugar industry and more recently of the docks, for housing, and to provide financing for welfare centres, and recreational and educational facilities. The total number of houses built by the Fund by the end of 1974 was about 3 500. The housing is provided on easy terms, which include 40-year interest-free mortgage loans. The Fund has also financed child and maternity care centres, recreation facilities, nutrition education, family planning, cooking, and a range of other educational and cultural programmes.

The Sugar Industry Pension Fund

4.11 The Pension Fund was established in 1956, but in fact replaced an older retirement fund established in 1946 which was a savings scheme rather than a pension fund. The present Fund currently has about 40 000 members. It is financed by contributions from employees, who contribute 5% of their salaries, and by matching contribution of 7.8% from employers. The normal retirement age is 60, but a 20-year contribution is the minimum requirement for a pension. The Fund is governed by a Board of 13 members including six employer and six employee representatives, who together elect a Chairman.

5. SUGAR INDUSTRY RESEARCH AND EXTENSION

Mauritius Research Council (MRC)

5.01 Government has proposed the establishment of a Mauritius Research Council with a view to coordinating scientific and technical research within the country and encouraging the application of research results to a further exploitation of the country's resources. Although the MRC has not yet been established, a first step has been taken by the setting up of a Research Advisory Committee. Membership of this committee comprises representatives of the Mauritius Sugar Industry Research Institute, the Ministry of Economic Planning and Development, the University of Mauritius, and the Chief Agriculturist of the Ministry of Agriculture who acts as Chairman.

Mauritius Sugar Industry Research Institute (MSIRI)

5.02 MSIRI enjoys a high reputation in the sugar world for its research activities. It was founded by the sugar producers of the island in 1953. Before that, sugar research was conducted by the Sugar Cane Research Station, which was a division of the Department of Agriculture. In 1953 the Research Station's activities, with the exception of its extension services, were transferred to the newly established research institute.

5.03 MSIRI is financed by means of a levy on all sugar produced. The levy varied in 1979 between Rs8.6/t ($1) on small planters to Rs22.34/t ($2.58) on large planters and miller-planters. The total received in 1979 was Rs12.6 M ($1.45 M). The 1981 budget is Rs16 M ($1.85 M).

5.04 The main activities of MSIRI are diverse; it has departments dealing with Plant Breeding, Botany, Plant Pathology, Entomology, Cultural Operation and Weed Agronomy, Soils and Plant Nutrition, Irrigation and Drainage, Biometry and Sugar Technology. It is also active in food crop research, the Food Crop Agronomy division being mostly concerned with crops which can grow in sugar interlines or between crops in the virgin cane year. In spite of its general contribution to the sugar industry of Mauritius, MSIRI does not provide individual services or guidance to owner-planters. This function is performed by the Government Extension Services. Annex 1 lists MSIRI's major investigations into sugarcane by-products since 1972.

Extension and Research Services of the Ministry of Agriculture and Natural Resources and the Environment

5.05 Presently two divisions of the Ministry influence the sugarcane industry and the utilisation of sugarcane by-products.

5.06 The Extension Services Division This is an advisory service whose objective is to improve the standard of husbandry of the approximately 32 000 independent planters through provision of technical education and advice on the problems affecting their crops and livestock. The Service staff consists of 18 professionals, 12 of whom work in crops, four in livestock and two in administration. In addition to the professionals, there are 64 field assistants. The Extension Service runs five regional demonstration centres where farmers call for advice and where training courses in agriculture are held. The ratio of sugar extension workers to planters is around 1:500.

5.07 The Animal Production Division The Animal Production Division is responsible for the major part of the livestock research work conducted in Mauritius. It organises investigations at three livestock breeding stations: Richelieu, Curepipe and Palmar, where for more than a decade an intensive programme concerned with the utilisation of sugarcane by-products by livestock has been running in cooperation with FAO/UNDP.

5.08 Other divisions such as Animal Health, Entomology and Dairy Chemistry service the livestock industry that is potentially a major consumer of sugarcane by-products.

The University of Mauritius

5.09 The University of Mauritius consists of three schools, Administration, Agriculture and Industrial Technology. The primary purpose of the university is teaching at degree, diploma and certificate levels, but financial stringency (the 1979/80 budget was Rs14.3 M ($1.6 M) or about the same order as that of the MSIRI) necessitating a reduction in the number of students is compelling the university authorities to rethink their role and to place new emphasis on research and consultancy activities. The School of Agriculture has limited facilities for field research but the School of Industrial Technology is better placed to conduct research into sugarcane by-product production and utilisation.

6. DEVELOPMENT ORGANISATIONS

Development Bank of Mauritius (DBM)

6.01 DBM was created in 1966 to provide long term finance to agriculture and for the establishment of new industries. At the date of its latest accounts, for the year ended 30 June 1980, its loan porfolio was as follows:

DBM: loan portfolio 30 June 1980

	Rs M	%
Textiles	67	32
Agriculture	36	17
Food processing	15	
Livestock	10	
Fishing and fish processing	4	
Sugar cane	4	
Other agriculture	3	
Hotels	29	13
Metal works	14	7
Chemicals	5	2
Small enterprises	8	4
Other industries	53	25
	212	100
US$	24.45 M	

In addition, Rs16 M ($1.8 M) were invested in equity holdings, and Rs71 M ($8.2 M) (net of depreciation) in industrial estates at Coromandel and Plaine Lauzun. Assets invested in development represent 89% of total gross assets.

6.02 Of DBM's total capitalisation, Rs72 M (18% - $8.3 M) represent shareholders' (ie government's) funds, and Rs295 M (75% - $34 M) are in the form of long-term loans. At 30 June 1980 these were as follows:

DBM: borrowings at 30 June 1980

		Rs M drawn down @ 30 June 1980
IDA	US$7.5 M)	
IBRD	US$26 M)	108
African Development Bank	EUA2 M	18
Industrial Development Bank of India	Ind Rs50 M	16
CCCE (Caisse Centrale)	FF12 M	2
European Investment Bank	EUA3 M	6
Bank of Mauritius	Rs5 M	-
Government of Mauritius		142
Others		3
		295 ($34.1 M)

6.03 Rates of return on average investments during the year ended 30 June 1980 were:

	%
Loans and equity	10.7
Property	9.4

Administrative charges were 1.3% of average capital. Lending rates at 30 June 1980 were:

a) Medium/Large Scale Industrial Loans

- In foreign currency for all lines of credit except	13.0%
- CCCE (Caisse Centrale)	10.5%
- International Development Bank of India	10.5%

b) Small scale industrial loans

- Up to Rs 25 000 ($2 900)	9.0%
- Over Rs 25 000 ($2 900)	12.0%

c) Agricultural loans

- Up to 10 arpents (4.2 ha)	8.5%
- Over 10 and up to 50 arpents (4.2-21 ha)	10.0%
- Over 50 and up to 200 arpents (21-84 ha)	12.0%
- Over 200 arpents (84 ha)	13.0%

The interest rates on deposits were as follows:

a)	Savings	9.5%
b)	Fixed Deposits	
	12 months	11.50%
	24 months	11.75%
	36 months	12.0%

6.04 Average interest payable on borrowings was 7.4%. Total return on equity was 10%, and a dividend of 3.75% was paid. Accounts for the years ending 30 June 1980 and 1979 are provided in End Table 2.

The Mauritius Cooperative Central Bank Limited (MCCB)

6.05 MCCB began business in 1948. Its purposes are to finance the agricultural cooperative movement and to strengthen the corporate bodies (eg cooperative credit societies and cooperative marketing societies) for the use of all involved in agriculture. It accepts deposits from members and from other lenders.

6.06 At 29 February 1980, MCCB had 328 members, of whom 242 (74% holding 99.7% of the shares) were working in agriculture, livestock and fisheries. Of these, 179 (55%) were involved in sugarcane production and marketing. Loans outstanding at that date amounted to Rs83.6 M, ($9.6 M) the details being as follows:

MCCB loan portfolio at 28 February 1980

	Number	% of short term	Rs M	% of short term
Short term loans ($7.9 M)	609	100	68.6	100
Sugar industry -				
cultivation and crop	450	74	50.4	73
Other expenditure	28	5	0.5	1
Livestock and fisheries	2	-	-	-
Industry	14	2	4.1	6
Savings and loans	2	-	0.1	-
Housing	12	2	6.7	10
Services and industries	15	2	0.3	1
Secondary cooperatives	4	1	0.5	1
Parastatal bodies	4	1	4.9	6
Personal and professional	78	13	1.1	2
Medium term ($1.16 M)	2 522		10.1	
Other ($0.57 M)	NA		4.9	
			83.6 ($9.6 M)	

The majority of medium term loans were for housing and other property investment.

6.07 Advances and other accounts, Rs83.6 M ($9.6 M), represented 75% of gross funds of Rs111 M ($12.8 M). These were as follows:

MCCB: Sources of funds at 28 February 1980

	Rs M	%
Shareholder funds	13	12
Deposits	81	73
Bank of Mauritius	15	13
Other	2	2
	111 ($12.8 M)	100

6.08 Average interest received on advances in the year ended 28 February 1980 was 10.2%. Interest paid on deposits was 8.3%. However interest rates rose during the year, and MCCB had to increase rates payable to depositors on 1 November 1979 to 9.5% on savings deposits and 10.5-12.5% on fixed deposits.

Administrative expenses were 1.6% of average total assets for the year. No dividend was paid. Summarised amounts appear at End Table 3.

7. OTHER INSTITUTIONS

The Agricultural Marketing Board (AMB)

7.01 AMB was formed in 1963 to promote the production of locally consumed foodstuffs by providing guaranteed markets to producers at fair prices. The last available accounts, for 1978, show finances of Rs17.5 M ($3 M) provided by government, used principally (Rs16.6 M net - Rs20.6 M gross) ($2.8 and $3.4 M) for the provision of fixed assets - warehouse and office buildings (Rs14.9 M gross - $2.5 M) and refrigeration and ventilation plant (Rs3.8 M gross - $0.63 M).

7.02 A gross profit of Rs1.5 M ($250 000-8.3% of net assets) was made in 1978; the net profit after charging administration expenses, depreciation and interest was Rs40 000 ($6 700).

The Central Electricity Board (CEB)

7.03 CEB was constituted under Ordinance No 32 of 1963. Installed capacity at 31 December 1979 was:

CEB: installed capacity at 31 December 1979 and 1980

	MW	%
Thermal	123	77
Hydro	23	14
	146	91
Purchases	15	9
	161	100

Units generated in 1979 and in 1980 were 355 GWh. In 1979, 295 GWh were sold; this is 2.5 times the 1970 figure. Units generated were as follows:

CEB: units generated in 1979 and 1980

	1979		1980	
	GWh	%	GWh	%
Thermal	270	76	245	69
Hydro	59	17	83	23
	326	-	328	92
Purchases	26	7	27	8
	355	100	355	100

There are two thermal stations of approximately equal size, and five smaller hydro stations. The purchases were from 15 of the 21 sugar factories and from one tea factory, at an average price in 1979 of approximately Rs0.11/kWh (US¢ 1.3).

7.04 The net assets employed amounted to Rs574 M ($66.2 M) at 31 December 1979; Rs247 M ($28.5 M) are self-generated funds, of which Rs203 M ($23.4) represent the surplus arising from a revaluation of fixed assets in 1979. Loans are as follows:

CEB: Borrowings 31 December 1979

		Rs M	Repayable in 1980
Government of Mauritius		107	54
IBRD		16	-
CCCE (Caisse Centrale)		87	-
UK government, ODA		14	-
Indian line of credit		7	-
European Investment Bank		34	-
Citibank		37	-
CEB pension funds		13	-
Others		5	-
	Rs	320 M	54
		($36.9 M)	-

7.05 Total income from the sale of electricity in 1979 was Rs194 M ($22.4 M) (1978 Rs141 M or $16.3 M) made up as follows:

Mauritius: electricity sales 1979

	Rs M	GWh	Average price Rs/KWh	Average price US¢/kWh
Domestic	79	133	0.59	6.8
Commercial	52	68	0.76	8.8
Industrial	56	79	0.71	8.2
Irrigation	4	10	0.45	5.2
Other	3	4	0.68	7.8
	194 ($22.4 M)	295	0.66	7.6

The increase in revenue over 1978 of 38% arose principally from tariff increases effective at the beginning of 1979; the increase in consumption was only 5%, compared to 12% for the average of the previous five years. The profit for 1979 was Rs45 000 ($6 100) (1978 Rs1.6 M or $267 000) against an expected profit of Rs10 M ($1.36 M). The shortfall resulted principally from the cost of repairs to the damage done by cyclone Claudette in December 1979. In addition, the depreciation charge was Rs3 M higher than in 1978 following the revaluation of fixed assets. Summarised accounts are at End Table 4.

Mauritius Meat Authority (MMA)

7.06 MMA was formed in 1974, being given powers to establish and manage abattoirs, to market meat, to control and regulate the sale of meat including (with the approval of the Minister of Commerce and Industry) fixing prices, and to licence other persons and premises to perform such functions. Under the Meat Act 1974 (as amended by the Meat (Amendment) Act 1981), no person shall - unless he has been licensed by MMA:

a) slaughter an animal for meat for sale (apart from wild pigs or deer as game);

b) construct, operate or maintain a place for the slaughter of meat;

c) sell, prepare or process meat or meat products, (subject to a proclamation yet to be made);

d) construct, operate or maintain a place for the prepacking or processing or storage of meat or meat products; and

e) sell or supply new hides or skins to tanneries.

No person - unlicensed by MMA - may provide any animal for slaughter by MMA.

7.07 The board consists of 10 members:

The Permanent Secretary, Ministry of Agriculture and Natural Resources and the Environment (Chairman)

Representatives of:
- Ministry of Finance
- Ministry of Commerce and Industry
- Ministry of Health
- Municipal Council of Port Louis

Mauritius Meat Producers Association
The butchers
The consumers
The Cooperative societies

7.08 MMA owns the abattoir at Roche Bois, on the northern outskirts of Port Louis. It consists of isolated sections for the slaughter of cattle, sheep/goats and pigs. It came into operation in September 1978. Its capacity is 5 000 t/y and in 1980 it produced 1 800 t. Its capital cost was Rs45 M ($7.5 M). The food hygiene laboratory has not been opened due to lack of funds, but the Ministry of Health is considering operating it.

7.09 MMA imported slaughter stock until April 1979, after which the butchers took over the trade. Total animals imported in 1979 were:

	Cattle	Sheep
MMA	1 542	794
Butchers	3 146	1 050

MMA slaughter statistics for 1979 were:

	Cattle	Goats & Sheep	Pigs
Local	3 863	19 [illegible]2	8 111
Imports	5 171	1 034	-

Mauritius Meat Producers Association (MMPA)

7.10 MMPA is an association of Mauritius livestock producers. Membership is about 25 and includes sugar estates, a number of livestock producers who are not sugar producers, Food and Allied Industries (who own one of the three feed mills in Mauritius), and the Pig Marketing Federation. At the end of 1980 members of MMPA were on record as owning 7 300 cattle, 560 sheep, 1 300 pigs, 700 000 poultry and 12 000 deer. The principal task of MMPA is to act as a lobby for the members' livestock interests.

END TABLES

The Mauritius Sugar Syndicate: statements of account for 1978/79 to 1980/81

End Table 1

1978/79 RsM	1978/79 $M	1979/80 RsM	1979/80 $M		1980/81 RsM	1980/81 $M
690 541 t		667 631 t		Sales 98.5° polarisation	477 051 t	
2 044	235.7	1 526	176.0	TOTAL RECEIPTS	1 640	189.2
				Expenses		
				Statutory		
17	2.0	15	1.8	Sugar Industry Development Fund	15	1.7
6	0.7	6	0.7	Sugar Industry Labour Welfare Fund	7	0.8
11	1.3	9	1.0	Arbitration and Control Board	9	1.1
141	16.3	281	32.4	Export Duty	256	29.5
12	1.4	13	1.5	MSIRI - Cess on production	14	1.6
0.1	1	1	0.1	Sugar Industry Reserve Fund	1	0.1
5	0.5	5	0.6	Export fee - Marine authority	4	0.5
193	22.3	330	38.1		306	35.3
				Direct and Financial		
7	0.8	8	0.9	White Sugar Manufacturing Premium	10	1.2
12	1.4	19	2.0	Warehousing	2	0.2
22	2.5	36	4.1	Weighing and Lighterage	6	0.7
11	1.3	24	2.8	Stevedoring and additional shipping charge	87	10.0
6	0.6	8	1.0	Shippers' Commission	9	1.1
9	1.1	12	1.4	Local Brokerage	3	0.4
8	0.9	17	2.0	Interest	-	-
1	0.2	-	-	Provision for ISO stock shipping and other charges	-	-
-	-	-	-	Dividend from Bulk Sugar Terminal Corporation	(13)	(1.5)
76	8.8	124	14.2		105	12.1
				Administration		
2	0.2	2	0.2	General Administrative and Office Charges	2	0.2
1	0.1	1	0.2	Laboratory Division	1	0.2
2	0.2	2	0.2	Overseas Representation and missions	2	0.2
5	0.5	5	0.6		5	0.6
459	52.9	274	31.6	TOTAL EXPENSES	416	48.0
1 585	182.8	1 252	144.4	Amount before deduction of SIFB premiums	1 224	141.2
104	12.0	90	10.3	Sugar Insurance Fund Board premiums	117	13.5
1 481	170.8	1 162	134.1	NET AMOUNTS TO PRODUCERS	1 107	127.7

APPENDIX 2

Development Bank of Mauritius: accounts for the years ended 30 June 1979 and 1980 End Table 2

1979 RsM	1979 $M		1980 RsM	1980 $M
		BALANCE SHEETS		
		ASSETS		
2	0.2	Fixed Assets	2	0.2
21	2.4	Current assets	35	4.1
233	26.9	Loans (less provisions)	276	31.8
73	8.4	Industrial estates (less depreciation)	71	8.2
329	37.9		384	44.3
		REPRESENTED BY		
31	3.6	Share capital	42	4.8
25	2.9	Reserves	30	3.5
		Borrowings:		
147	17.0	Government	142	16.4
111	12.8	Others	153	17.7
15	1.6	Other liabilities	17	1.9
329	37.9		384	44.3
		PROFIT AND LOSS ACCOUNTS		
		INCOME		
19	2.2	Interest earned	23	2.7
2	0.2	Dividends	4	0.5
7	0.8	Rent	7	0.8
2	0.2	Other	2	0.1
30	3.4		36	4.1
		EXPENSES		
16	1.8	Interest paid	20	2.3
4	0.4	Administration	5	0.5
2	0.3	Depreciation	2	0.3
5	0.6	Provisions for debts	1	0.2
27	3.1		28	3.3
3	0.3	Net profit for year	8	0.8
11	1.3	Add: Balance brought forward	1	0.2
(2)	(0.2)	Less: Dividend	(2)	(0.2)
(11)	(1.2)	Transfer to general reserve	(6)	(0.7)
1	0.2	Balance carried forward	1	0.1

The Mauritius Cooperative Central Bank Limited: accounts for the years ended 28 February 1979 and 29 February 1980

End Table 3

1979 RsM	1979 $M		1980 RsM	1980 $M
		BALANCE SHEETS		
		ASSETS		
3	0.4	Fixed Assets	5	0.6
20	2.4	Current assets	23	2.7
72	8.2	Loans (less provisions)	83	9.6
95	11.0		111	12.9
		REPRESENTED BY		
10	1.1	Share capital	10	1.2
3	0.3	Reserves	3	0.3
		Borrowings:		
15	1.7	Bank of Mauritius	15	1.7
1	0.1	Other Mauritian Banks	1	0.1
66	7.8	Deposits	81	9.4
-	-	Other liabilities	1	0.2
95	11.0		111	12.9
		PROFIT AND LOSS ACCOUNTS		
		INCOME		
7	0.7	Interest earned	8	0.9
EXPENSES				
5	0.5	Interest paid	6	0.7
1	0.2	Other	2	0.2
6	0.7		8	0.9
1	-	Net profit for year	0	-
1	0.2	Add: Balance brought forward	2	0.2
2	0.2	Balance carried forward	2	0.2

APPENDIX 2

The Central Electricity Board: accounts for 1978 and 1979 — End Table 4

1978 RsM	1978 $M		1979 RsM	1979 $M
		BALANCE SHEETS		
		ASSETS		
357	41.2	Fixed Assets a/	804	92.7
110	12.7	Less depreciation	294	33.9
247	28.5		510	58.8
57	6.6	Capital work in progress	25	2.9
1	0.1	Loans receivable	1	0.1
63	7.3	Current assets	78	9.0
4	0.4	Exchange equalisation account b/	54	6.2
372	42.9		668	77.0
42	4.8	Less current liabilities	54	6.2
330	38.1		614	70.8
		FINANCED BY		
39	4.5	Capital reserves	247	28.5
6	0.8	Revenue reserves	7	0.8
263	30.3	Long term loans	320	36.9
13	1.5	Short term loans	27	3.1
9	1.0	Overdrafts	13	1.5
330	38.1		614	70.8
		PROFIT AND LOSS ACCOUNTS		
280 GWh		Units sold	295 GWh	
142	16.4	Sales	194	22.4
1	0.1	Rent of meters	1	0.1
2	0.2	Miscellaneous income	3	0.3
145	16.7		198	22.8
102	11.7	Cost of sales	125	14.4
43	5.0	Gross profit	73	8.4
29	3.3	Administration	46	3.3
-	-	Cyclone reinstatement	11	1.3
1	0.2	Deficit in Rodrigues	1	0.1
11	1.3	Interest	15	1.7
41	4.8		73	8.4
2	0.2	Net profit for year	-	-
3	0.4	Add balance brought forward	5	0.6
5	0.6	Balance carried forward	5	0.6

a/ Fixed assets were revalued at current costs in 1979. A surplus of Rs203.5 M was taken to capital reserves.

b/ The Exchange equalisation account represents the difference between the year-end values of foreign borrowings and the book values.

ANNEX 1

MSIRI: RESEARCH INTO SUGARCANE BY-PRODUCTS
1972-81

MSIRI: research into sugarcane by-products, 1972-81

1972-73	-	Effects of steam treatment of bagasse under pressure. Pressures of 14-18 bar A gave best conversion of insoluble matter into soluble material.
1973	-	Derinded sugarcane as cattle feed. 9-10 months old cane could be used for cattle feeding.
1974	-	Steamed bagasse for sheep. Digestibility appeared to be 14%.
	-	Whole cane as cattle feed.
	-	Disposal of vinasse. Trials with fodder yeast *Candida utilis* increased pH from 4 to 7, but cooling the vinasse would be a problem.
	-	Production of *Candida utilis* in a 100 ℓ pilot plant.
	-	Production of alcoholic beverages from cane juice. Normal techniques with *Saccharomyces oviformis* and *S. carlsbergensis* give a cider-like beverage which should be test marketed in the tourist trade.
1975	-	Digestibility of steamed and unsteamed bagasse, with molasses and spent yeast incorporated.
	-	Digestibility of dried filter mud (scums) on sheep. Over-drying depressed digestibility from 20% to 10%, but is essential to stop fungal development.
1976	-	Storage of filter mud up to 8 weeks. A loss of up to 20% dry matter occurs, mostly sugars.
	-	Ensilage of fresh cane tops. Best results were obtained with 0.25% nitrogen as ammonia or ammonium sulphate and 5% molasses. Comparison with fresh fodder revealed no significant difference in liveweight gain of cattle.
	-	Microbial protein synthesis from various cane by-products. Results were not encouraging.
1977	-	Ensilage of filter mud. Trials gave unpleasant smells.
	-	Carotene in cane tops silage. Even though ensilage lowers the carotene content, the latter is still adequate.

APPENDIX 2
Annex 1

1978 - Deficiencies in protein and glucose precursors in diets for ruminants based on sugarcane. Supplements which resist degradation in the rumen should be used.

- Effect of molasses on washed cane fibre. Even with incorporation of molasses at 50%, only a slight improvement in digestibility was noted.

1979 - Incorporating sweet potato foliage and tubers in a bagasse - molasses diet for ruminants. This produced an increase in total intake though not dry matter intake.

Present and proposed:

- Separation of protein from cane juice in a discontinuous separator. Trials gave low digestibility.
- Disposal of vinasse.
- Disposal of fly ash by scrubbing.
- Energy balances of sugar factories. Equipment has just been donated.
- Producer gas, on a grant from Sweden. Equipment has been ordered from India.

APPENDIX 3

ALTERNATIVE TECHNOLOGY IN SUGARCANE PRODUCTION AND PROCESSING

CONTENTS

SUMMARY

1. The Mauritius Sugar Industry Research Institute has devoted substantial investigation resources to the problems of interline cropping of sugarcane, with considerable success. As a consequence a number of crops are now grown interline in Mauritius. Those of interest to this study are crops that provide livestock feeds, such as maize. At present the total quantity of maize grown (1 171 t in 1979) is small, mainly due to problems concerned with the mechanical harvesting and drying of the crop. It is expected, however, that these problems will be overcome and that up to 15 000 t of maize will be harvested in 1990. Other interline crops which would be useful for providing livestock feeds are soyabeans and groundnuts.

2. The 'Comfith' method of sugarcane processing is briefly described but as the process has still to be proved to be either technically or commercially viable it is not recommended for further consideration in Mauritius.

3. Ethanol can be produced from sugarcane juice or directly from whole cane. Production from sugarcane juice would not appear to be viable in Mauritius as the country can export all the sugar that it produces. Production from whole cane has yet to be demonstrated on an industrial scale.

1. PRODUCTION

Interline cropping

1.01 With the major part of the cultivable land planted with sugarcane, considerable quantities of food are imported. The Government is interested in reducing these imports in order to conserve foreign exchange, and as a consequence there has been constant pressure on the sugar industry to diversify cropping.

1.02 In these circumstances the sugar industry has had two major options; either to reduce the sugarcane area or to attempt diversification within the existing sugarcane fields by introducing interline cropping. The industry chose the latter option and the Mauritius Sugar Industry Research Institute (MSIRI) has devoted substantial investigational resources to the problems of interline cropping, and can claim considerable success for their efforts.

1.03 Potatoes, maize, groundnuts, upland rice, beans, tomatoes and other vegetables are all being grown interline at the present time. Maize is a major constituent of livestock rations and if the livestock industry expands, thereby increasing the utilisation of sugarcane by-products, maize consumption will also increase. In addition, unripe maize can be used for silage production and the empty maize cob and stover are useful roughage feeds. Groundnuts and soyabeans would make good interline crops; they have higher protein contents than maize (End Table 6, Appendix 5), and are less likely than maize to have an adverse effect on sugarcane. Groundnut cake is also a useful animal feed, but at present the small interline groundnut crop is sold for human consumption.

1.04 In Mauritius sugarcane is normally grown in rows 5 ft (1.5 m) apart and miller/planters usually harvest at least 8 ratoon crops. Maize can be planted between each row of virgin cane and high yields are obtained, but the yield of sugarcane is significantly reduced 1/. Potatoes are therefore the most usual interline crop in the virgin cane. The presently accepted method of interline cropping maize is to plant it between every second sugarcane row, so that the distance between maize rows is 3 m. The MSIRI has shown that if the distance between sugarcane rows alternates between 3 ft (0.9 m) and 7 ft (2.1 m), then two rows of maize can be grown in the wide interlines 1/. Maize may be grown as an interline crop until the third ratoon, but rarely for a longer period. In the drier areas it is best planted in July, in the first fields to be

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1/ MSIRI Annex 1, Report 1976.

replanted after cane harvesting and it requires irrigation. In the wetter highland areas it is best planted after harvesting has been completed, in February or March. Average yield throughout the country in 1979 was 2.5 t/ha.

1.05 The tonnage grown (1 171 t in 1979) is still small. This has not been due to agronomic problems but to conservatism or the part of sugarcane growers; difficulties encountered in mechanically harvesting the crop; and the lack of drying facilities. One drier is in operation at the present time, but at least four driers are required if the targets of 5 000 t and 15 000 t in 1985 and 1990 are to be attained.

2. PROCESSING

Sugarcane separator equipment

2.01 The Lignex Sugar Cane Separator separates sticks of cane into three components - rind, pith and waxy epidermis. The rationale for the process is that, because the fibres in the rind are not broken up by the extreme methods normally used in sugar milling, they will be suitable for the production of high quality board or paper products. Simultaneously by removing the sugar-rich pith from the hard rind, sugar extraction can be accomplished by much less costly means than are normally employed.

2.02 The cane is fed by hand into a machine which chops it into suitable length billets. These are fed into the separator where an anvil splits the cane longitudinally into halves. The split lengths of cane are then flattened, and cutter heads scrape the pith from the rind. A second set of cutters then scrape the epidermis and wax from the outside of the rind. The three fractions are collected separately and passed to appropriate processing stations.

2.03 The process known as 'Comfith' has been under development in Barbados and elsewhere for over fifteen years under various names and with different sponsors. A very small plant was used for the experimental processing of sugarcane as a livestock feed in the early 1970's in Mauritius, but is no longer used. To date no commercial installations have been commissioned, which is probably indicative of the technical and commercial problems to be overcome. The unit size of the plant is small, at 400 tc/d. This means that the capital and operating costs, together with those of any associated sugar extraction plant, distillery or board plant, will tend to be high on a unit cost basis. It is also believed that a significant amount of sugar will be lost in the rind, rendering the process even less economical. In a study carried out in the Caribbean region the method was not recommended even as a source of livestock feed 1/.

2.04 It is felt that the process has yet to be proved to be both commercial and technically viable by the current owners, Hawker Siddeley Canada Limited. Until this has been done it is not recommended for further consideration.

Ethanol from sugarcane juice

2.05 Clarified sugarcane juice from sugar factories can be used as a feedstock for ethanol, using similar technology to that described for molasses fermentation and distillation in Appendix 6A. Sugarcane juice from the mill has a fermentable sugars content of between 11% and 13% which must be concentrated to between 17% and 20% before fermentation in order to ensure optimum sugar concentration in the fermenting vessels.

2.06 The capital cost of a cane juice distillery is comparable to that of a molasses distillery: the cost of providing an evaporator to concentrate the cane juice is similar to the cost of the molasses clarification equipment. This assumes that the cane juice is adequately clarified at the factory, which is usually the case and the clarification equipment at the distillery is unnecessary.

2.07 The following table indicates that a typical distillery requires cane juice from 740 tc/d to product 50 000 ℓ/d of alcohol.

Distillery capacity	50 000 ℓ/d
Fermentation efficiency	90%
Distillation losses	7.5%
Fermentable sugars required	95.4 t/d
Extraction efficiency	95%
Fermentable sugars extracted from cane 2/	12.9%
Cane required	740 t/d
Sugar production foregone @ 11% cane	81.4 t/d

1/ Lambie & Company (1975) Canefeed livestock study for Caribbean Development Bank.

2/ Sucrose % cane = 12.6%; expressed as

fermentable sugars	13.2%
Reducing sugars % cane - estimate at 3% sucrose	0.4%
	13.6%
at 95%	12.9%

2.08 The utility requirements of a cane juice distillery are slightly greater than those for a molasses distillery because of the need to evaporate the cane juice. For comparison the utilities consumptions are:

Basis per litre of 99.7% ethanol

	Molasses	Cane juice
Steam	420 kg	520 kg
Cooling Water	336 ℓ	355 ℓ
Electricity	0.144 kWh	0.125 kWh

2.09 Any sugar used for ethanol production would have to be diverted from the export market which, in good production years, would be the world market. Considering that all the sugar which Mauritius produces can be exported, and that it is unlikely there will be any major increase in the area of land for growing sugarcane, the production of ethanol from cane juice will show smaller returns than exporting sugar directly. Daily revenues would be as follows:

81.4 t sugar at 20 US¢/lb (44 US¢/kg-Rs4 510/t)	:	Rs367 000
50 000 ℓ alcohol at Rs3.31	:	Rs165 000

Ethanol from cane tops and whole cane

2.10 A process has been developed in South America which ferments cane tops directly, without extraction of fermentable sugars. Whole cane has also been successfully fermented in this way. The cane and tops are chopped into short billets between 5 and 10 mm long and fed into a fermenter to which boiling water is added. The slurry is cooled to 30°C before the yeast is introduced. The solids are centrifuged after fermentation and ethanol is distilled in the usual manner.

2.11 The process has not yet been demonstrated on a full scale plant, but the economics of ethanol production from sugarcane based on pilot plant test results are encouraging, since there is no need for a conventional sugar mill.

APPENDIX 4

THE LIVESTOCK INDUSTRY: PRESENT SITUATION AND POTENTIAL

CONTENTS

CONTENTS

SUMMARY

1. The numbers and types of livestock in Mauritius are detailed. The most significant features are a major decline in the number of dairy cattle, from 42 000 in 1964 to 11 000 in 1981, and a large increase in poultry numbers and production during the same period.

2. The structure of the dairy industry, mainly comprising small cowkeepers, is very different to that of the beef sector in which the majority of the cattle are managed on estates. There are a few sheep, mainly on estates, and a much larger smallholder goat industry. Deer are now being farmed on some estates. Smallholders predominate in the pig industry, the majority being organised into cooperatives, whilst poultry meat but not egg production is dominated by two large firms.

3. It is easier and possibly more profitable to invest in non-ruminant rather than ruminant livestock production. Local production of beef, milk and sheep and goat meat are only 12, 7 and 8% respectively of total consumption of these products whilst 51 and 95% of pig and poultry meat and almost all eggs are locally produced.

4. During the period 1977-80 consumption of beef and sheep and goat meat has fallen and poultry meat has risen sharply. Pork and venison consumption have increased slightly. Milk consumption has been more or less steady whilst egg consumption has increased by about one fifth.

5. Constraints on the expansion of the livestock industry are discussed in some detail. A shortage of breeding and fattening cattle will be a major constraint but adequate numbers of other breeding livestock should be available. Sugarcane by-product feeds will be available for any forseeable expansion, though there is a shortage of grazing lands. This could be overcome to some extent by the utilisation of some forest land for grazing. Other major constraints are a shortage of trained animal husbandmen, low internal prices for milk and meat, lack of adequate marketing facilities and poor credit facilities for smallholders in some sectors of the industry.

6. Local milk production is likely to continue to decline for some time, though beef production will probably increase to provide up to 19% of consumption by 1990. Sheep production could increase slowly from a low base whilst goat production could be dramatically improved. Venison production is likely to increase slowly. Pig and poultry production levels depend on the prices of imported feeds.

7. In the dairy sector it is proposed that smallholder cowkeepers should be assisted to organise into producer cooperatives and that there should be a small levy on imported milk that would be used to provide a support price for locally produced milk. The beef sector requires better organised marketing arrangements and larger projects should be granted development certificates similar to those available to industrial projects. With adequate extension services and credit the goat industry could be rapidly developed. Present efforts to farm deer should be fully supported by Government. The industry requires training facilities and investigation programmes which are orientated to the practical application of new techniques in the field.

1. INTRODUCTION

1.01 For the following reasons it has been considered necessary to provide information on the present situation and potential of the Mauritius livestock industry.

a) Livestock, and in particular ruminant livestock, are consumers or potential consumers of all sugarcane by-products; molasses, bagasse, filter mud and cane tops.

b) A major programme, executed by FAO and funded by UNDP, has been conducted in Mauritius to demonstrate the technical and economic feasibility of producing milk and beef using sugarcane by-products as a basis for the feed supply and to investigate the nutritional limitations of such feeding techniques.

c) Apart from cereals and cereal products meat and dairy products are in total the most expensive group of foods imported into Mauritius representing during the 1974-80 period 14-30% of total food imports (Rs248 M in 1980).

d) Local production of beef, milk, and sheep and goat meat represents a small proportion of total consumption so that potential savings in import costs could be considerable if ruminant livestock production were to be substantially increased.

2. NUMBER AND TYPES OF LIVESTOCK

Number of livestock

2.01 Cattle Total cattle in Mauritius were 45 700 in 1964, but have decreased to an estimated 19 500 in 1981. Details of the variation in the total number of cattle during the last 60 years (1921-80) are shown in End Table 1 together with the composition of the national herd.

2.02 The milking cattle herd increased to a peak of approximately 42 000 in the 1960s and has since rapidly declined in number. A majority of milking cattle have always been owned by individual cowkeepers, who are usually landless, and the drastic fall in number since the mid-sixties may be attributed partly to social changes, such as improved education and employment opportunities for the rural population, and partly to low milk prices, a lack of processing and organised marketing facilities and a scarcity of forage when cane tops are unavailable, due to increasing use of herbicides at the edges of fields and roads.

2.03 In the 1920s approximately 40% of the national herd consisted of draught animals. Today, on account of the mechanisation of cultivation and transport operations, there are very few, though the Government livestock stations report that there has been a recent increase in demand for them.

2.04 The number of herd cattle, managed primarily for beef production, slowly declined until the late 1950s, but has since increased. The decline was possibly due to a decrease in the available area of rough grazing, whilst the more recent rise is probably due to increased utilisation of sugarcane by-product feeds.

2.05 Sheep There are very few sheep in Mauritius, but there is some interest in the possibility of establishing a small viable sheep industry.

2.06 Goats The goat population appears to have stabilised at somewhat less than 100 000 head, after considerable expansion since 1964.

2.07 Pigs Few data exist but pig numbers appear to have fluctuated considerably during the last 16 years. There are indications that the number is at present increasing, but the market for pork and pork products is limited as they are only consumed by approximately one third of the population.

2.08 Poultry Poultry production has increased very rapidly during the last decade and the industry has become more specialised. Data on numbers are not readily available.

2.09 Deer Estimates of the number of deer in Mauritius vary widely. The team's opinion is that they number 25-30 000. As deer meat is consumed by all sections of the population and deer farming appears to be feasible, it is probable that the industry will expand and that deer numbers will increase in the future.

Types of livestock utilised

2.10 Milking cattle

a) Creole This indigenous breed of milking cattle is a Bos taurus type of distant European origin. It is a small, polled animal, usually possessing a white coat. It appears to be quite well adapted to local management and feeding conditions. For a considerable period a proportion of the Creole population has been crossbred with Friesian, so that Creoles as a percentage of the national herd have decreased. For example, in 1964 77% of all female milking cattle were Creole, whereas in 1978 they numbered only 71%. With the reduction in the total number of milking cows that is now occurring (see End Table 1) there is some danger that this genetically valuable breed will be drastically reduced in number.

b) Friesian Some purebred Friesians have been imported, as has Friesian semen. As a consequence there are some purebred Friesians as well as many crossbreds in the milking herds.

c) Other Dairy Shorthorn, Simmental and Sahiwal cattle have been imported and there are some purebred as well as crossbred cattle of these breeds at the livestock stations and on private farms.

2.11 Beef and draught cattle In general the beef herds are heterogenous in composition. A major contribution to their genetic makeup has come from the local Zebu, descendants of draught cattle used on the sugar estates in the past. There have also been genetic contributions from the milking herds and from imported beef breeds such as the American Brahman, Boran, Ongole, Santa Gertrudis and Charolais. There are some purebreds in the herds, but in general there appears to be an attempt to breed *Bos indicus x Bos taurus* crossbreds for feedlot purposes, with the larger enterprises importing purebred bulls and/or semen.

2.12 Sheep The majority of the small number of sheep managed in Mauritius are descendants of sheep imported from Rodrigues. They appear to be crossbreds between Black Head Persian and European-type sheep and there has been some recent crossbreeding with Dorset Horn and Wiltshire. In general they are small and carry some wool that is gradually shed. Approximately half the population have Black Head Persian markings, but only a limited number possess a desirable smooth hairy coat.

2.13 Goats Mauritian goats are an admixture of many types. They tend to be small, prolific and possess many coloured but smooth coats. At the Palmar Livestock Breeding Station there are purebred herds of Anglo-Nubian and Jamnapari and Government has stated that it will upgrade the Mauritian national goat herd using Anglo-Nubians.

2.14 Pigs No doubt pigs of many different breeds have been imported in the past. At present the majority of pigs are crossbred, with some purebred Wessex Saddleback, Large White and Landrace.

2.15 Poultry Grandparent stock are imported by local firms from large scale poultry breeding organisations overseas. The majority of production stock are bred locally.

2.16 Deer The deer Cervus timorensis was introducted from Indonesia by the Dutch in the mid-seventeenth century. It is a medium-sized animal, mature stags weighing up to 120 kg.

3. PRESENT STRUCTURE OF THE INDUSTRY

Milking cattle

3.01 The dairy industry has always been primarily a smallholder industry. In 1964 there were 41 968 head of milking cattle (End Table 1). There were 21 913 owners and only 19% of the herds contained three or more animals 1/. Although the total number of milking cattle declined drastically between 1964 and 1978, due to the reasons stated in paragraph 2.02, there being 13 452 head of cattle and approximately 11 000 owners in 1978, the structure of the industry has not changed. At the present time the number of smallholder cowkeepers is less than it was in 1978, and there are herds of moderate size on three Government livestock breeding stations that provide breeding stock to both the cowkeepers and to four private dairy farms, Savannah, Mon Trésor and Union sugar estates, and Belle Isle Farm.

3.02 The majority of smallholder cowkeepers do not farm any land. Their cattle are managed under cover, being fed cane tops as roughage during the cane cutting season and any other roughage that may be available on field and road edges during the remainder of the year. Some cowkeepers feed concentrates whilst others feed whatever waste feed products are available. On two of the private farms, there are no pastures and the cattle are fed cane tops in season, and cane top silage and/or fodder cane out of season, together with molasses and concentrates.

Beef cattle

3.03 The structure of the beef industry is very different to that of the dairy industry. There are some smallholders producing finished fat beef cattle, and others sell young cattle to larger producers. At present, approximately 12 holdings could be listed as larger producers, seven of

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1/ Milliken M (1968). Dairying in Mauritius. Revue Agricole et Sucriere de l'Ile Maurice, 47, (2), 1-64.

them owning feedlots. In addition, there is a beef herd at one of the Government livestock breeding stations. Some feedlot owners purchase unfinished local cattle, either from the few larger holdings that possess breeding herds but no feedlot, or from smallholders. Others who experience difficulty in obtaining a sufficient number of local cattle for fattening have been importing unfinished cattle, mainly from South Africa. A few producers possess integrated operations with their breeding herd supplying their feedlot with cattle. Almost half the national beef herd are concentrated on Medine sugar estate. This firm manages its breeding herds on pasture in the daytime and in feedlots at night. In the feedlot the roughage ration consists of cane tops in the cropping season and canetop silage and/or cut fodder cane and grass out of season, together with molasses at the average rate of 3.5 kg/head/day, and brewers' grain.

Sheep

3.04 There is no sheep industry at present, but a few individuals are interested in attempting to establish one; the government manages a small flock of sheep at the Palmar Livestock Breeding Station. There are probably no more than 700 head of sheep in the country, but one flock numbers 500 and it is the intention of the owners to expand it to 1 000 head in order to establish the first viable sheep enterprise.

Goats

3.05 Goats are owned by some 20 000 smallholders, the average herd size being about five. In addition, there is a herd at Palmar Livestock Breeding Station comprising goats of two exotic breeds: Jamnapari and Anglo-Nubian. The majority of the smallholder's flocks are housed and fed any forage or other feed that may be available, though some of the larger flocks are herded on rough grazings and grass verges, particularly in coastal and drier areas.

Pigs

3.06 There are at present no large scale pig producers though there have been some units in the past. Approximately 70% of the smallholder producers are members of the Mauritius Pig Marketing Federation and are organised into 14 Pig Marketing Cooperatives. The Cooperatives provide loans for pig housing and for the purchase of feeds and the Mauritius Pig Marketing Federation has recently completed a processing plant at Terre Rouge that at present is purchasing 15 pigs/day, but will in the near future raise throughput to 30 pigs/day.

Poultry

3.07 Two large scale integrated producers, operating two of the three feed mills in Mauritius, dominate poultry meat production. Smallholder and back-yard producers are, however, more important than the large scale operators in egg production. Improvements in productivity have been made during the last decade, but the industry now depends almost entirely on imported feeds.

Deer

3.08 Government and private land owners are now aware of the potential that exists for intensive deer farming. This is the result of a number of expert reports that have been made during the last decade and progress by private estates and the Forest Service of the Government in adopting recommended deer farming practices. The most ambitious pilot trial is located at Case Noyale on the Belle Ombre estate, where a commercial deer feedlot has been established and where it is expected that a stocking rate of approximately 35 deer/ha may ultimately be achieved. At present there are 15 members of the Mauritius Meat Producers Association reporting that they own more than 200 head of deer and who may be expected to be interested in intensive deer farming.

Feed sources

3.09 Concentrate feeds are produced in three feed mills (para 4.02, Appendix 5). The first to be established is owned and operated by the Government and mainly supplies rations for Government livestock breeding centres and to the smallholder cowkeepers. The other two mills commenced operations more recently. They are privately owned by companies that are also directly involved in poultry production. Details of the current production of the three mills and the types of livestock rations produced are provided in End Table 2 Appendix 5. Most of the feeds and feed supplements used in the mills are imported (61 000 t in 1980); details are in End Table 2 of this Appendix. It will be seen from this table that there was a major decline in prepared feed imports between 1978 and 1979, when the first private mill commenced operation, together with a sharp increase in the volume of imports of oil-seed by-products, meat and fish meal and unmilled cereals (mainly maize). Further details of the availability of local feeds are provided in paragraphs 5.04-5.06 of this Appendix and in paragraphs 6.01-18 of Appendix 5. In general it is easier and possibly more profitable at the present time to utilise rations produced mainly from imported feeds to raise non-ruminant livestock (poultry and pigs), than it is to grow or organise a supply of local feeds in order to raise ruminant livestock (cattle, sheep and goats).

Extension services

3.10 An integrated extension service is provided for crop and livestock farmers, the country being divided into 25 zones with a technical officer in overall charge of extension in each zone. In addition, artificial insemination (AI) and animal health services are provided for livestock farmers by the Division of Veterinary Services, that also operates an Animal Health Laboratory and organises disease surveys and quarantine services.

3.11 The AI service is expected to provide for the needs of the smallholder cowkeepers. Friesian semen is provided in the Moka and Upper Plaines Wilhems areas and Creole semen elsewhere. An average conception rate of 55% was achieved in 1980. Larger livestock owners can obtain advice and training in AI techniques for their own staff.

3.12 In general, the overall animal health situation is quite good, no major tropical diseases being endemic. However, the present policy of importing animals for slaughter or for fattening and then slaughter, particularly from South Africa, obviously increases the possibility of importing tropical disease and/or parasites. This policy should be phased out as soon as possible.

3.13 The smallholder cowkeepers depend a great deal on the AI and health services, but the larger livestock owners are not well satisfied with the services provided, particularly the animal health services. They would obviously be well advised to support private veterinary practice, through their organisation the Mauritius Meat Producers' Association. It should be relatively easy to organise private veterinary practice at the present time as there is, for the first time, a surplus of trained veterinarians in Mauritius.

Education and training

3.14 A major handicap of the livestock industry is that there is no tradition of livestock husbandry in the country and no practical training facilities available in livestock management. It is possible to obtain training in the scientific aspects of livestock husbandry at the University of Mauritius. This institution provides a degree course in agriculture (including livestock husbandry) and a diploma course in agriculture and sugar technology.

Research

3.15 Livestock investigational work is primarily the responsibility of the Ministry of Agriculture and Natural Resources and the Environment but some investigations of the feeding value of specific sugarcane by-products have been conducted in the Schools of Agriculture and Industrial Technology of the University of Mauritius and in the Mauritius Sugar Industry Research Institute.

3.16 A major part of the Ministry's livestock investigational work is conducted, under the auspices of the FAO/UNDP Project MAR/75/004 at Richelieu and Palmar Livestock Breeding Stations. The milk and beef investigational programme is supervised by a visiting FAO consultant Dr R Preston in animal production. It has two major components. The first is to demonstrate the technical and economic feasibility of producing milk and beef, using by-products of the sugar industry as the basis of the feed supply, whilst the second is to investigate the nutritional limitations governing the utilisation of sugarcane and its by-products in the production of milk and meat. The Project has provided large scale feedlots at Richelieu and Palmar and a ruminant laboratory at Richelieu in order to provide adequate facilities for the programme.

3.17 FAO/UNDP have now provided project support for the cattle industry for more than a decade. Local production of milk and meat has fallen during the same period and although a decline in the number of smallholder cowkeepers and hence in the production of milk was probably inevitable (see para 2.02) there has not yet been any major compensatory increase in the number of cattle reared on estates. It can be claimed, however, that the FAO consultant's basic philosophy, 'that cattle can be fed to a large extent on sugarcane by-product feeds', has now been generally accepted within the Ministry and by the majority of cattle producers. Unfortunately insufficient attention has been paid as to how this philosophy can be translated into practice and the cattle industry encouraged to expand.

Marketing

3.18 In 1965 the Agricultural Marketing Board organised milk collection centres, but these ceased to operate after one year and since that time there have been no national milk marketing facilities. The milk produced by the smallholder cowkeepers is either consumed by the family (20% of the total produced according to Milliken (1968) 1/ or sold to small, local retailers. Milk from the private herds is not usually processed and is sold locally.

3.19 Cattle for slaughter are purchased from producers by one of the butchers' organisations and slaughtered at the Central Abattoir sited at Roche Bois and owned by the Mauritius Meat Authority (MMA). Meat is transported by MMA to retail outlets. Producer prices are recommended by MMA

1/ Milliken M (1968). Op cit.

but at present cannot be enforced. The majority of larger producers are organised in the Mauritius Meat Producers Association and are dissatisfied with existing marketing arrangements. The situation is further discussed in paragraph 5.10.

3.20 Sheep and goats are also purchased by one of the butchers' organisations and slaughtered at the MMA abbattoir. All deer are slaughtered on the holdings and marketed in accordance with custom.

3.21 The marketing interests of the majority of smallholder pig producers are protected by the Mauritius Pig Marketing Federation. Marketing of poultry meat is dominated by the two large scale producers. Egg marketing arrangements appear to be satisfactory.

Credit

3.22 The larger-scale enterprises, including the miller-planters obtain credit either through the commercial banks or the Development Bank of Mauritius. The latter had 18 livestock industry loans outstanding on the 30 June 1980 for a total of Rs9.75 M ($0.95 M). The loans are mainly for 7-10 years, at a lower rate of interest than other loans.

3.23 There are at present one cooperative cowkeeper society and the 14 pig credit and marketing societies already mentioned. These societies are all members of the Mauritius Cooperative Central Bank Ltd (MCCB). In the year ending 28 February 1981, MCCB had made medium term loans of Rs186 000 to the Mauritius Pig Marketing Federation to lend to their members. The MCCB in association with the German development bank KfW is also providing a Rs1.8 M loan to finance the new pig meat processing plant at Terre Rouge.

4. LOCAL PRODUCTION, IMPORTS AND CONSUMPTION OF EDIBLE LIVESTOCK PRODUCTS

Local production

4.01 Meat

a) Beef The number of cattle slaughtered in 1980 was 10 091. Details of the number of local and imported live cattle slaughtered in official premises and their total carcass weight during the period 1975-80 are given in End Table 3. It will be seen that there has been a major reduction in the number of local cattle slaughtered, from 6 285 in 1975 to 2 884 in 1980 presumably as a result of the decline in total cattle numbers (End Table 1), and a substantial increase in the total number of cattle imported for slaughter. The number of local cattle illegally slaughtered is unknown; estimates vary from five to 50% of the total slaughtered. For the purpose of this study illegal slaughter has been estimated to be of the order of 15% of the total slaughtered (End Table 4). If this estimate is used there would have been an offtake of 23% from the national herd in 1978; this is of the order that would be expected. The extent of the decline in beef production during the period 1975-80 is well demonstrated by the carcass data in End Table 3. In 1975 76% of the fresh beef available in Mauritius was produced from cattle of local origin, whereas in 1980 the percentage was only 12% (End Table 4).

b) <u>Sheep and goat meat</u> In 1980 18 122 sheep and goats were slaughtered. The total number of sheep and goats slaughtered in official premises during the period 1975-80, together with their total carcass weight are shown in End Table 5. Of this total 4.7% were imported live for slaughter during the period 1979-80. Sheep represent about 17% of the total number of sheep and goats slaughtered and almost all were imported. A relatively small number of goats are imported for slaughter. The number of sheep and goats illegally slaughtered is likely to be quite high and for the purpose of this study it is estimated to be 50% (End Table 4) of the total slaughtered in official premises.

c) <u>Pig meat</u> In 1980 9 157 pigs were slaughtered. The number slaughtered in official premises and the quantity of pig meat available are shown in End Table 5. No pigs are imported for slaughter and the extent of illegal slaughter is unknown. For the purpose of this study illegal slaughter is estimated to be 25% of the total slaughtered in official premises.

d) <u>Poultry meat</u> The Ministry of Agriculture's estimate of poultry meat produced in 1980 was 5 348 t. The quantity of poultry meat produced more than doubled between 1974 and 1979-80 (End Table 5). The data include estimates of the amount of poultry meat produced by both large and small producers.

e) Deer meat Until recently deer have been hunted and the carcasses disposed of by the hunters according to traditional practice. As the total deer population is not known but is estimated to be of the order of 25-30 000 and the total killed annually is unrecorded, it is difficult to estimate total carcass weight available per annum. For the purpose of this study it is assumed that offtake is of the order of 20% and that average carcass weight is 40 kg; total carcass weight would be 220 t. The offtake of a stable deer population could of course be higher, but it is assumed that the present attempt to establish deer farms reduces current offtake as a larger number than normal are retained for breeding purposes.

f) Total meat production Estimates of total local meat production in 1980 are given in End Table 4. It will be seen that poultry provide almost three quarters of the meat produced in the country, whilst cattle produce less than one tenth. Deer provide more meat than sheep and goats.

4.02 Milk For the purpose of estimating total milk production it has been assumed that half the total milking cattle population are potential milk producers, that in any one year three-quarters of these are lactating and that their average production is 4.5 ℓ per day for a 300 day lactation period. Using these parameters estimates of total milk produced in the census years 1964 and 1978 are 21.3 and 8 M ℓ respectively, indicating a drastic decline in production since 1964. There has been a further reduction in the milking cattle population since 1978 and it is estimated that total production of milk in 1980 was of the order of 6 M ℓ.

4.03 Eggs The Ministry of Agriculture and Natural Resources and the Environment estimate that total egg production increased very rapidly during the seventies, being 32.8 M in 1974 and 66.0 M in 1980. Large scale commercial units only contributed 6.8 M eggs to the 1980 total, the remainder being produced by smallholders or in backyards. Estimates of milk, milk products and egg production are provided in End Table 6.

Imports

4.04 Live animals for slaughter The number of live cattle imported for slaughter has risen from 1 844 in 1975 to 7 309 in 1980 (End Table 3). The total numbers of live sheep and goats imported for slaughter were small, being 1 054 and 774 in 1979 and 1980, respectively.

4.05 Imports of edible livestock products The value of edible livestock product imports increased very considerably during the period 1974-80. In 1974 the value of imports of meat, dairy products and eggs represented 14.3% of total food imports whilst by 1980 they represented 22.9%. The value of meat imports as a percentage of total food imports increased more rapidly than those of dairy products (End Table 7), whilst the value of egg imports remained negligible.

4.06 Meat and meat products Imports of fresh, chilled and frozen (fcf) meat of cattle, sheep and goats, pigs and poultry, during the period 1974-80, rose from 1 745 to 3 486 t (End Table 8). These represent 60-70% by volume of total meat imports, the remainder, including dried, salted, canned and potted meat extracts, etc, being included in one category in End Table 8. Imports of other meat in 1980 are, however, classified by animal origin in End Table 4. As there are difficulties in categorising all imports of meat products by animal origin, the total for the 1980 importation of 'other meat of all types' in End Table 8 does not equate with the total of imported 'meat preparations' in End Table 4. It will be seen from End Table 8 that during the period 1974-80 beef imports trebled, and sheep and goat meat imports almost doubled in volume.

4.07 Milk and milk products Imports of fresh milk and other types of milk expressed as fresh milk equivalents rose from 42 861 t in 1974 to 78 118 t in 1980 (End Table 9). Imports of fresh milk are small in volume but more than quadrupled between 1974 and 1980, whilst imports of dried milk almost doubled. Evaporated and condensed milk imports varied considerably from year to year but there did not appear to be any trend for them to increase. There were substantial increases in the volume of butter, ghee and cheese imports, milk products that are not produced in Mauritius.

4.08 Eggs Egg imports have been small throughout the 1974-80 period.

Consumption data

4.09 Estimates of the total quantities of meat and meat products, milk and milk products and eggs available for consumption in 1980 are shown in End Tables 4 and 6, together with details as to the percentage of each product produced locally. Meat and milk production from local ruminant livestock were small proportions of the total meat and milk available for consumption, whereas a high proportion of non-ruminant livestock products were produced locally, using large quantities of imported feed. Several estimates of the average consumption per head per year of meat and meat products, milk and milk products and eggs are provided in End Table 10. The estimates vary but demonstrate similar general trends. Between 1977 and 1980 beef and mutton and goat meat consumption declined by approximately one third whilst poultry meat consumption increased by some two thirds. Pork and pork product consumption increased slightly as did venison consumption. Milk consumption appeared to remain stable whilst egg consumption increased slightly.

4.10 The reasons for changes in the consumption of different livestock products are complex but the most important is probably relative prices. As will be seen from End Table 12, between 1977 and 1980 poultry meat prices have not risen to the same extent as beef, mutton and goat meat prices. Frozen meat prices have risen more rapidly than those of fresh meat, whilst the fresh milk price has risen more rapidly than milk product prices.

5. CONSTRAINTS ON THE INDUSTRY

Availability of livestock

5.01 There is an acute shortage of cattle for fattening purposes. Hence the importation of unfinished cattle from South Africa for feedlot fattening operations. This situation is partly due to the limited number of large breeding herds that have been established and partly to the rapid decline in the number of milking cattle in the smallholder sector and hence in the number of male calves, sterile females and cull cows available for fattening. For similar reasons there is a shortage of available breeding cattle in the private sector.

5.02 At the same time on account of budgetary restraint, the Government livestock breeding stations at Richelieu, Curepipe and Palmar have limited the size of their breeding herds, still further reducing the availability of breeding animals. As the total sheep population is small it is difficult to purchase any type, but the goat population is sufficiently large to provide an adequate base for a rapid expansion in number and Palmar Livestock Breeding Station can provide Anglo-Nubian breeding stock for upgrading purpose. The deer population could be rapidly expanded if such action was essential.

5.03 There would be no major difficulty in rapidly increasing the number and genetic quality of the non-ruminant pig and poultry population.

Availability of animal feed

5.04 The area of grassland available in Mauritius is a major constraint on the expansion of cattle breeding operations as only 4% of the total land area or approximately 7 500 ha can be classified as grassland (see End Table 13). However, a further 15% of the total land area (another 28 000 ha) that is classified as forest is scrub and/or rough grazing. At present much of this area is used for extensive deer management. In addition there is some grazing available under trees in the planted forest (another 28 000 ha) and it should be possible to develop integrated livestock/forestry systems in specific areas.

5.05 Adequate supplies of sugar cane by-product feeds (molasses, bagasse, filter mud and sugar cane tops) are likely to be available throughout the period to 1990 (see paragraphs 3.01 to 3.08, Appendix 1) even if expansion of the ruminant livestock industry is maximised.

5.06 The only major constraint on the importatation of the components of livestock concentrate feeds will be the availability of foreign exchange. It is hoped that local production of maize, a major component of concentrate feeds, will increase from a present level of approximately 1 000 t/y to 5 000 t/y in 1985 and 15 000 t/y in 1990. In addition it is understood that government has approved in principle the construction of a flour mill. This will provide local supplies of cereal by-products for inclusion in livestock rations, with a corresponding reduction in imports. There may also be a modest increase in the local production of protein concentrate feeds if interline cropping of crops such as peanuts can be expanded, and available slaughter house offals processed.

Animal health

5.07 The most important animal health constraint is that the presence of very large numbers of the fly Stomoxys nigra can make the outdoor management of cattle during the cane harvesting season somewhat hazardous in the wetter regions of the country. Stomoxys calcitrans, a species that breeds in manure, is well controlled by introduced parasites, but the control of S.nigra has proved to be more difficult. This fly breeds in damp trash in the sugar cane fields. An attempt to control it by breeding and releasing sterile males has now been abandoned and the use of chemical control methods is advocated, especially in feedlots. Three parasites have been introduced and these have effected partial control. The major difficul' / is that after the sugar cane harvesting season ends the numbers of flies and hence parasites are reduced to very low levels; at the beginning of the next season the fly has reproduced more rapidly than the parasite. It is now proposed that control of the fly by the parasites can be made more effective by breeding parasites in captivity at the end of the cane harvesting season and releasing them in large numbers when the fly begins to reproduce rapidly. It is also possible that current and proposed changes in cane harvesting technology will help to reduce fly numbers. Burning the cane reduces the quantity of trash available as a breeding habitat for the fly: so does mechanical removal of tops for direct feeding or ensilage purposes, as considerable quantities of trash are removed with the cane tops.

Management and training

5.08 A lack of practically trained animal husbandmen and skilled workers is undoubtedly a major constraint on the development of the livestock industry.

Research

5.09 Although a vigorous livestock research policy has been pursued by the Ministry of Agriculture and Natural Resources and Environment during the last decade, the record of practical application of investigational findings within the industry has been disappointing. It is therefore suggested that a reorientation of research policies is now required.

Marketing

5.10 A major constraint to milk production is the low price of milk on the local market. At present, the price is fixed by Government at Rs2/ℓ ($0.20), whilst production costs are estimated to be of the order of Rs5-6/ℓ ($0.49-0.59). For comparison, the price of imported milk powder (26% fat) is about Rs15/kg cif ($1.46) for bulk imports in 25 kg bags. This equates to about Rs1.5/ℓ ($0.15) or Rs1.7/ℓ ($0.17) retail. Any price increase for liquid milk to bring it more in line with production costs would therefore be likely to adversely affect consumption in favour of imported milk.

5.11 The low price of milk also tempts producers to adulterate supplies, discouraging still further consumption of locally produced milk.

5.12 Marketing of livestock is the responsibility of MMA, whose powers are being set out in the Meat Act 1974 (as amended). MMA, however, has not exercised all its powers, causing problems for producers.

5.13 MMA has the authority to fix the price of meat and meat products. An excercise was carried out to calculate the cost of production of finished cattle, and an ex-farm price of Rs18.13/kg ($1.77) liveweight was arrived at. However, MMA is unable to guarantee that producers will receive this price, as it is not exercising its authority to purchase all slaughtered livestock. MMA also has power to import livestock for slaughter, the control of imports being essential if fixed prices are to be maintained. However, apart from one importation on which MMA made a large loss, it has not been able to exercise any control over imports.

5.14 Until MMA is able to exercise the powers that legally it possesses it is almost impossible to ensure that producers get a fair and guaranteed price for their slaughtered cattle, sheep and goats.

Credit

5.15 Although large scale enterprises can usually obtain credit from the commercial banks or the Development Bank of Mauritius, there is a lack of incentive for investment in enterprises that require long-term credit, such as beef and dairy cattle breeding projects and this must act as some constraint on the development of the industry.

5.16 Apart from the smallholder pig keepers, the majority of whom are organised into a Cooperative Pig Marketing Federation, credit facilities are a considerable constraint on the development of smallholder livestock production.

6. POSSIBILITIES FOR AN EXPANDING LIVESTOCK INDUSTRY

6.01 Possibilities for expanding the livestock industry during the next decade depend upon:

a) the level of consumption of livestock products by the population; and

b) what proportion of these products can be locally produced utilising existing resources at prices acceptable to consumers and profitable to producers.

Livestock products consumption potential to 1990

6.02 Forecasts have been made to show the order of magnitude of consumption of the various types of meat in 1985 and 1990. Estimates of income elasticity of demand and cross price elasticity of demand for meats have not been calculated. Instead, more general estimates have been made to predict a 'high' and a 'low' range of consumption.

6.03 From the Government's Two Year Plan it can be calculated that the total meat consumption per head was expected to grow at 2.7% per annum over the period 1978-80. However, the Plan assumed a real growth rate for the economy of 5-6% per annum. In fact meat consumption has fallen since 1978 (End Table 10) and a much slower rate of economic growth is forecast for the period to 1990. In these circumstances the 2.7% growth rate must be seen as optimistic and has been used to derive the 'high' range forecast figures for meat consumption.

6.04 FAO forecasts to 1985 for the four main meat types suggest an average per head growth rate in developing countries of 1.2%/y 1/. There is obviously a wide range of growth rates between different countries. However, for Mauritius, this average figure must be considered conservative. As such it has been used to describe the 'low' range forecast figure for meat consumption.

6.05 The two growth rate figures have been applied to the 1980 meat consumption estimates (End Table 10), the resulting forecasts for consumption in 1985 and 1990 being as follows:

	Total meat consumption t/y	
	1985	1990
High range	17 172	21 325
Low range	15 952	18 420

End Table 11 provides details of meat consumption.

6.06 The data in End Table 10 suggest that consumption of milk was stable during 1977-80 and it is not considered that there will be any major change during the next decade, though there may be some slight upwards trend. Egg consumption has risen slightly during the 1977-80 period and may continue to increase slowly during the next decade. All supplies of butter, ghee and cheese will continue to be imported and changes in consumption are likely to depend primarily upon fluctuations in import prices.

1/ FAO (1979) Projection of meat production, demand and trade to 1985. CCP: ME 79/4. FAO: Rome.

The effect of constraints on local production

6.07 Even if beef producers are encouraged to expand production by the introduction of liberal price and credit policies, and by improvements in animal health and other services and reorientation of investigation work, the existing evidence suggests that the availability of a sufficient supply of breeding and fattening cattle will be the major constraint on production during the next decade. If it is assumed that there are approximately 8 500 head of beef cattle in Mauritius at the present time and the following production parameters are used; 2.5% bulls for breeding purposes; calving rate 75%; heifers first calving at 2-3 years of age: 12.5% culling of breeding cows and infertile heifers; mortality up to weaning 2.5% and after weaning 2.5%; bulls fattened in feedlots after two years of age; and average carcass weight of slaughtered cattle (bull and culled females) 180 kg 1/; then it is estimated that the beef cattle population, the number of cattle slaughtered annually and the total quantity of meat produced in Mauritius in 1985 and 1990 would be as follows:

	1985	1990
Beef cattle	14 600	25 100
Animals available for slaughter (fattened cattle and culled females)	2 120	3 636
Total quantity of carcass beef produced (t)	381.6	654.5

6.08 Beef would also be available from the national milking herd. It is estimated that there are 11 000 head of milking cattle at the present time and it is reasonable to assume that the total population is still falling and that any measures that the government might take to stimulate milk production would at first only slow down the reduction in number of cattle. The milking cattle population might possibly return to the 1981 total by 1985 and then start to increase. However, dairy cattle populations do not increase very rapidly as annual culling rates have to be as high as 25%. This is because milking cattle are not only culled for infertility and age but also for low milk production. Other production parameters that would be different from those in the beef herd are the calving

1/ These parameters are generally the same as those proposed by a Chamber of Agriculture Committee that published in 1978 a plan entitled 'Meat and Milk Production and the Private Sector' except where the UNIDO team considered they were too optimistic.

percentage that might be higher at 80% and mortality that would be of the order of 12% 1/. Using these parameters it is estimated that in 1985 and 1990 the milking cattle population, the number of cattle slaughtered annually from the national dairy herd and the quantity of beef produced per year would be as follows:

	1985	1990
Milking cattle	11 000	11 500
Animals available for slaughter (fattened cattle and culled females)	2 420	2 437
Total quantity of carcass beef produced (t)	435.6	438.7

6.09 The estimated quantities of beef produced by the national beef and dairy herds in 1985 and 1990, together with what these quantities represent as percentages of estimated consumption are as follows:

	1985	1990
Total quantity of beef produced locally (t)	817	1 093
Local production as percentage of estimated consumption:		
High range	15%	17%
Low range	17%	19%

6.10 As 12% of beef consumed was locally produced in 1981, the general trend during the next decade could be towards increased self sufficiency, but there is obviously no danger that any measures that government might take to stimulate beef production could lead to local over-production. It could be argued that the team has been unduly cautious in their choice of production parameters, but more optimistic parameters would not unduly affect the general conclusion. There could also be large imports of breeding cattle, particularly dairy cattle, so that the national herd could be increased more rapidly. This is a procedure that has been followed by some other developing countries, such as Malaysia. In addition there could also be large imports of immature cattle for fattening purposes, a procedure that could increase the utilisation of sugarcane by-product feeds but might also increase the risks of disease and/or parasite introduction.

1/ FAO (1974). Milk and Meat Project, Mauritius. AGA:DP/MAR/67/504. Tech.Rep.No 5. FAO: Rome.

6.11 The small size of the sheep population precludes any major expansion in mutton production, but the goat population could be expanded very rapidly if there were no other constraints to production. The latter include inadequate year-round feed supplies, limited extension services and the absence of market and credit facilities. Land, at present used for extensive deer management could be made available for expansion of the production of 'farmed' deer if husbandry problems, now being investigated, can be solved.

6.12 A major constraint on pig production is the limited size of the local market for pork and pork products on account of dietary traditions.

6.13 The major constraints on poultry meat and egg production are likely to be consumption potential and the cost of importing feeds.

7. REQUIREMENTS FOR AN EXPANDING LIVESTOCK INDUSTRY

Milk production

7.01 It will be difficult to prevent milk production declining still further before any expansion of the industry can be considered. It should also be recognised that the two different segments of the industry, the few estate producers and the many smallholder cowkeepers, are faced with different problems. However, a more realistic price for milk, indexed in future to the costs of production would materially assist both sectors. It is considered that the price received by producers could be substantially increased, whilst that to consumers would be only slightly increased, if a producer subsidy was introduced financed by a levy on imported milk and milk products. Since 93% of all milk consumed is imported, the levy on imports could be very small, and still finance a relatively large subsidy on locally produced milk.

7.02 A realistic price for fresh milk would probably encourage the few estate producers to stay in business and possibly other estates to commence dairying; as estates can obtain credit, a substantial market for milk exists within their boundaries and adjacent to them and they have access to ample supplies of sugarcane by-product feeds.

7.03 The situation is very different for the smallholder cowkeepers. A substantial price increase will possibly discourage those already in the industry from selling their cows but it is unlikely to encourage new entrants as there are many negative factors still operating, such as difficulty in acquiring credit and a sufficient all-year-round supply of roughage feeds together with the social factors mentioned in paragraph 7.02.

7.04 In these circumstances it appears to be essential for Government to assist smallholder cowkeepers to form more producer cooperatives with adequate provision of financial and other assistance. The cooperatives could then organise large scale production of sugarcane top silage for feeding as roughage during the out-of-crop period, bulk purchase concentrate feeds, etc.

7.05 If smallholder milk production continued to contract and estate production began to expand slightly, it would be necessary to ensure that heifers and breeding cows from the smallholder section are not slaughtered but retained to assist in the eventual expansion of the national dairy herd. This would require intervention by Government through the agency of the Mauritius Meat Authority (MMA). This organisation would have to be instructed to purchase and hold for eventual sale any fertile heifers and young cows offered for slaughter.

Beef production

7.06 There is some evidence that beef cattle numbers have been expanding on the sugarcane estates during the last few years (paragraph 2.04). If the momentum of this expansion is to continue it is vital that the cattle owners receive a realistic price for their cattle and are able to market them in a rational manner. Government has created in MMA the organisation that could accomplish these aims, presently with the powers but not the funds to purchase all slaughter cattle and thus establish a relevant price and market policy.

7.07 Government could also encourage production by granting Agricultural Development Certificates, similar in scope to Industrial Development Certificates, to larger beef cattle units, as has been suggested many times, and by improving services to the industry. Any expansion of the dairy industry would also increase the number of cattle available for slaughter.

7.08 As there is very little grazing land available in Mauritius (paragraph 5.04) and any expansion of the beef industry will require expansion of breeding herds, immediate consideration should be given by Government to the possibility of leasing suitable forest areas to cattle breeders for the establishment of integrated beef cattle breeding/forestry operations.

Sheep and goat production

7.09 There is some land available that is suitable for sheep husbandry, particularly in coastal areas and on hills in the dry zone, but there is an insufficient land resource for any major sheep industry. Nevertheless, a small flourishing industry could be established if there were a meaningful investigational programme that could solve current problems, and a more vigorous animal health extension programme.

7.10 Expansion of the goat industry should be awarded some priority. The breeding herd base already exists, as does a local market. In the cane harvesting season ample supplies of sugarcane tops are available as roughage feed and it is suggested that in the out-of-season period roughage could be obtained from tree forage; the trees being planted along roadsides and on the edges and in the odd corners of fields. Very suitable species are Leucaena leucocephala and Sesbania grandiflora. In similar environmental circumstances a goat industry is being rapidly expanded in Fiji.

Deer production

7.11 As stated in earlier sections investigations into the feasibility of deer farming are accelerating and this development should be encouraged by Government, possibly by tax concessions. The estates with existing deer herds are the natural centres to accomplish this work as adequate supplies of sugarcane by-products such as molasses, cane tops in season and filter mud are available as supplementary feeds to deer grazing on improved pastures. Government should also consider whether it would be possible to lease additional forest land for extensive deer management in those areas not suitable for integrated beef cattle/forestry operations. In addition MMA should be requested to study requirements for marketing surplus deer meat that may ultimately become available from deer farming operations.

Pig and poultry production

7.12 Pig production by smallholders appears to be developing along sound lines but additional credit facilities will be required by the cooperatives and Government should expand and improve the genetical base of the purebred pigs raised on the livestock breeding stations so that a national crossbred breeding policy can be pursued by the cooperatives. Some control of pig product imports may also be required in order to encourage production at the new Terre Rouge factory.

7.13 It is considered that no major measures are required by Government to stimulate the poultry industry, except those that would encourage egg production by smallholders and householders mainly for home consumption.

Education and training

7.14 Serious consideration should be given by Government to the problem of training skilled animal husbandmen. It is suggested that the possibility of establishing a small intermediate level training centre should be investigated. This could be affiliated to an appropriate educational institute but sited at a major livestock enterprise. The training provided should be primarily of a practical nature.

Research

7.15 It is important to coordinate the efforts of the institutions involved in livestock research (para 3.15). In the 1975-80 Development Plan the Government proposed the creation of a Mauritius Research Council (MRC). Pending the formation of the MRC an ad hoc Committee has been established for research coordination purposes. It is assumed that this Committee will clearly demarcate the responsibilities of each institute, propose joint investigation work where this is clearly desirable, assess results and propose methods by which promising investigational results can be more effectively translated into practice.

7.16 Although, as stated in paras 3.15-17, the Ministry of Agriculture and Natural Resources and the Environment has conducted a major livestock research programme for more than a decade, this has been primarily directed towards solving the problems of the utilisation of sugarcane by-products by milking and slaughter cattle to the relative neglect of problems encountered in the management of other domestic species. The exception to this statement is the establishment of breeding herds or flocks of sheep, goats and pigs.

7.17 If promising investigation results are to be more effectively translated into practice, and the scope of the livestock research programme is to be enlarged, reorientation of the existing programme is urgently required. Such a programme reorientation should include:

a) An appraisal, using economic analysis, of the possibility of utilising in practice promising investigation results on the feeding of sugarcane byproducts to livestock;

b) The conduct of a series of pilot trials outside the livestock stations with private enterprise at the sites of existing or projected livestock projects in cooperation, in order to ascertain what practical problems might be encountered in the application of new techniques. This series should include the following investigations:

i) the use of sugarcane by-product feeds and in particular those listed in para 7.01-7.06, Appendix 5:

- at a dairy on a sugar estate that possesses no pasture;
- at a small cowkeeper cooperative dairy farm;
- at an estate where pasture is available for the breeding herd; and
- in a feedlot operation;

ii) the most suitable method of managing sheep (Mont Choisy, where there are already at least 500 sheep, would be the most suitable site);

iii) the use of sugarcane by-products (particularly cane tops) and tree forage for goat production; and

iv) integrated breeding cattle/forestry operations.

In addition, the existing deer farming investigations at Case Noyale should be assisted.

b) That cooperative projects should be established in order to investigate complex problems such as the most suitable method of utilising vinasse or the extraction of protein from sugarcane juice during the factory operation.

END TABLES

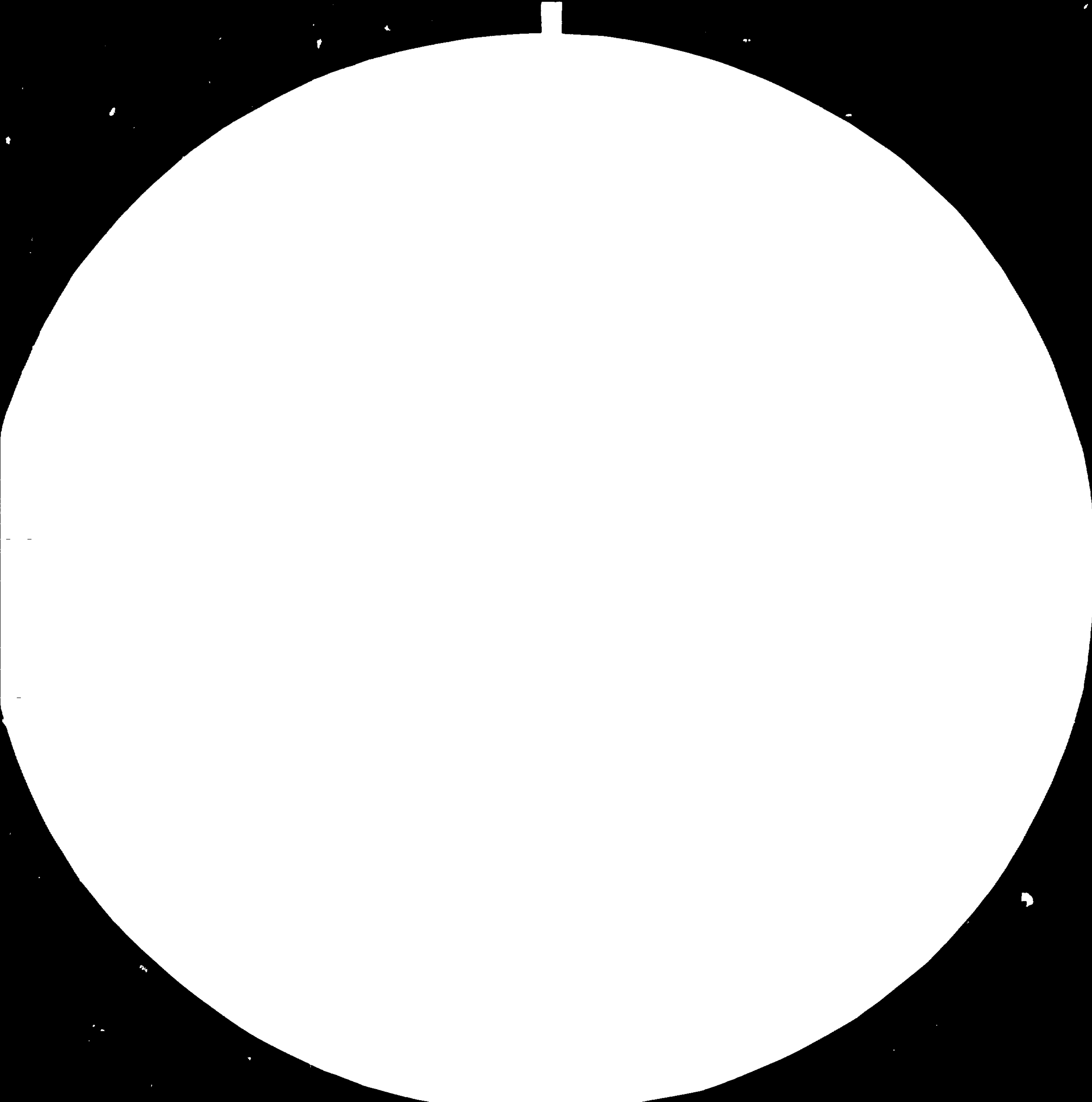
Mauritius: the livestock population, 1921-81

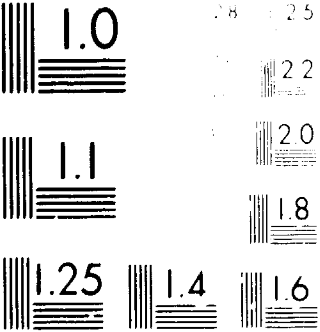
End Table 1

	1921	1930	1940	1943	1950	1956	1964	1973	1978	1981
Cattle (total)	44 339	31 869	29 077	39 655	40 282	41 978	45 683	41 090	21 052	19 500 a/
Milking	18 625	19 891	17 835	28 620	32 143	37 599	41 968	35 905	13 452	11 000 a/
Other	25 714	11 978	11 242	11 035	8 139	4 379	3 715	5 185	7 600	8 500 a/
Herd (beef)	8 100	6 035	6 434	5 823	5 070	2 475	2 620	4 146	NA	NA
Draught	17 614	5 943	4 808	5 212	3 069	1 904	1 095	1 039	NA	NA
Sheep	NA	NA	NA	NA	NA	NA	358	NA	700	700 a/
Goats	NA	NA	NA	NA	NA	NA	65 591	97 656	95 000 a/	NA
Pigs	NA	NA	NA	NA	NA	NA	3 279	8 364	6 000 a/	NA
Poultry	-	-	-	-	-	-	-	420 000	NA	NA
Deer	NA	NA	NA	NA	NA	NA	NA	NA	NA	25-30 000 a/

Notes: a/ UNIDO team estimates based on information received from the Mauritius Meat Producers Association, the Mauritius Meat Authority and other sources.

Sources: Central Statistics Office, Ministry of Agriculture and Natural Resources and the Environment, Mauritius Meat Authority.




1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

Mauritius: imports of animal feeds, 1974-80 (t)

End Table 2

Feed commodity	1974	1975	1976	1977	1978	1979	1980
Hay and other forage	41.5	99.3	0	5.2	433.9	NA	NA
Cereal grain by-products	1 449.9	610.3	552.2	1 158.0	2 662.0	1 425.0	2 000.0
Oil-seed by-products	591.9	758.4	686.1	1 382.3	2 600.3	4 242.0	5 128.0
Meat and fish meal	297.4	201.9	187.7	243.1	1 457.5	2 401.0	1 754.0
Prepared feeds a/	17 504.8	19 074.9	20 913.9	19 297.7	11 773.1	3 728.0	3 602.0
Unmilled cereals b/	2 646.5	2 616.6	1 427.8	5 604.7	10 851.0	14 111.0	12 300.0
				('000 Rs)			
All concentrate feed and unmilled cereals c/	25 531.1	27 163.5	30 666.4	43 405.8	41 568.0	54 259.0	60 968.0

Notes: a/ Mineral and vitamin supplements and pet foods included in this 'commodity'.
b/ Mainly maize (varies from 66 to 96% of the total).
c/ Not including 'hay and other forage'.

Source: Annual Reports of the Customs and Excise Department.

Mauritius: numbers and carcass weights of slaughtered local and imported cattle, 1975-80

End Table 3

Year	Numbers of cattle slaughtered			Carcass weights (t)		
	Local	Imported	Total	Local	Imported	Total
1975	6 285	1 844	8 129	738.2	229.6	967.8
1976	8 010	816	8 826	932.7	123.2	1 055.9
1977	8 948	1 282	10 230	1 052.5	204.7	1 257.2
1978	4 140	3 569	7 709	458.0	698.8	1 156.8
1979	3 863	5 171	9 034	571.2	1 079.4	1 650.6
1980	2 884	7 309	10 091	453.3	1 379.2	1 832.5

Note: Cattle from Rodrigues are included in the imported group.

Sources: 1975-78: Bi-annual Digest of Statistics (1978). Central Statistical Office.
1979-80: Mauritius Meat Authority.

Mauritius: estimates of total quantity of meat available in 1980

End Table 4

Type of meat	Local production: Slaughtered at official premises (t)	Local production: Estimate of illegal slaughter (t)	Local production: Total (t)	Local production: % total local meat	Imports: Imported livestock slaughtered in Mauritius (t)	Imports: F.c.f. meat a/ (t)	Imports: Meat preparations b/ (t)	Imports: Total (t)	Total local and imports (t)	Local as % total
Beef	453.3	68.0	521.3	7	1 379.2	2 061.0	318.0	3 758.2	4 279.5	12
Sheep and goat meat	117.0	58.5	175.5	2	19.7	1 734.0	263.0	2 016.7	2 192.2	8
Pig meat	605.1	151.3	756.4	11	Nil	24.0	693.0	722.0	1 478.4	51
Poultry meat	5 348.0 c/	c/	5 348.0	76	Nil	162.0	111.0	273.0	5 621.0	95
Venison	Nil d/	d/	220.0	4	Nil	Nil	Nil	Nil	220.0	100

Notes:
a/ F.c.f.: fresh, chilled and frozen meat.
b/ Ministry of Economic Planning and Development estimates.
c/ Backyard poultry slaughter included in total.
d/ All deer slaughtered in field.

Sources: Annual Reports of the Customs and Excise Department.
Ministry of Economic Planning and Development.
Ministry of Agriculture and Natural Resources and the Environment.

Mauritius: numbers and carcass weight of slaughtered animals other than cattle, 1974-80

End Table 5

Year	Sheep and goats		Pigs		Poultry	Deer
	Number slaughtered	Carcass weight (t)	Number slaughtered	Carcass weight (t)	Estimated total carcass weight (t)	Estimated total carcass weight (t)
1974	NA	NA	NA	NA	2 030 a/	NA
1975	14 105	204.8	9 216	745.1	NA	NA
1976	16 093	166.4	8 215	604.4	NA	NA
1977	19 407	197.9	7 266	471.8	NA	NA
1978	21 382	173.6	8 240	440.6	NA	NA
1979	20 806	154.6	8 111	527.0	5 550 a/	217.0 a/
1980	18 122	136.7	9 157	605.1	5 348 a/	220.0 b/

Notes: a/ Estimate provided by the Ministry of Agriculture and Natural Resources and the Environment.
b/ Estimate made by the UNIDO team.

Sources: 1975-80: Bi-annual Digest of Statistics (1978). Central Statistical Office.
1979-80: Mauritius Meat Authority.

Mauritius: milk, milk products and eggs available in 1980 (t) End Table 6

Product	Local production	Imports	Total	Local as % total
Fresh milk equivalent	6 000	78 118	84 118	7
Butter and ghee	Nil	924	924	0
Cheese	Nil	1 081	1 081	0
Eggs	3 916	35	3 951	99

Sources: Annual Reports of Customs and Excise Department.
Ministry of Agriculture and Natural Resources and the Environment.

Mauritius: total values of food imports, 1974-80 (RsM) End Table 7

Type of import	1974	1975	1976	1977	1978	1979	1980
Food and live animals	500	460	487	582	697	756	1 084
Meat and meat products	23.8	35.2	47.6	73.8	88.4	104.6	104.7
Meat and meat products as % total food and live animal imports	4.8	7.7	9.8	12.7	12.7	13.8	9.7
Dairy products	47.6	56.5	67.0	92.8	89.1	119.9	143.2
Dairy products as % total food and live animal imports	9.5	12.3	13.8	15.9	12.8	15.9	13.2
Eggs	0.1	neg	neg	neg	0.2	0.1	0.2

Source: Annual Reports of the Customs and Excise Department.

Mauritius: imports of meat, 1974-80 (t) End Table 8

Type of meat	1974	1975	1976	1977	1978	1979	1980
Fresh chilled and frozen (f.c.f.) meat:							
Beef	694	1 928	2 850	4 017	4 286	3 265	2 061
Sheep and goat meat	921	1 699	1 737	2 593	2 220	1 605	1 734
Pig meat	4	2	2	3	50	66	29
Poultry meat	126	77	28	33	237	767	162
Total f.c.f. meat	1 745	3 706	4 617	6 646	6 793	5 703	3 486
Other meat of all types	1 160	1 458	1 490	2 125	1 991	NA	2 445
Total (all meat)	2 905	5 164	6 107	8 771	8 784	NA	6 431
F.c.f. meat as % total	60	72	76	76	77	NA	62

Source: Annual Reports of the Customs and Excise Department.

Mauritius: imports of milk and milk products, 1974-80 (t)

End Table 9

Type of milk product	1974	1975	1976	1977	1978	1979	1980
Fresh milk	37.1	39.0	31.4	117.8	96.2	167.0	171.0
Fresh milk equivalent:							
Evaporated and condensed milk	1 267.9	603.6	1 497.0	692.3	829.8	1 493.1	564.8
Dried milk	41 556.1	37 969.3	48 540.0	68 073.7	70 401.0	93 724.5	77 381.8
Total fresh milk equivalent	42 861.1	38 611.9	50 068.4	68 883.8	71 327.1	95 384.6	78 117.6
Butter and ghee	388.2	611.7	855.6	1 128.9	1 106.5	1 186.0	924.0
Cheese	689.8	597.8	710.3	956.7	763.8	897.0	1 081.0

Note: Fresh milk equivalents are calculated using data from USDA (1952). Conversion factors and weights and measures for agricultural commodities and their products. USDA/ERS: Washington.

Source: Annual Reports of the Customs and Excise Department.

Mauritius: estimated per head consumption of edible livestock products, 1977-80

End Table 10

	Meat products kg/head/year						Milk: fresh equivalent gm/head/day	Milk products kg/head/year		Eggs number/head/year
	Beef	Mutton and goat meat	Pork	Poultry	Venison	Total		Butter and ghee	Cheese	
1977	7.10 a/	3.20	1.30	3.60	0.17	15.37	250	-	-	60
	6.32 b/	3.48	1.43	3.72	NA	-	NA	-	-	NA
1978	7.00 a/	2.70	1.40	5.70	0.16	16.96	250	-	-	50-60
	6.43 b/	2.96	1.35	5.89	NA	-	NA	-	-	-
1979	5.40 a/	1.90	1.00	7.70	0.16	16.16	250	-	-	60-60
	5.86 b/	2.28	1.[illegible]7	7.06	0.26	16.93	NA	-	-	-
1980	4.62 c/	2.37	1.60	6.07	0.24	14.90	249	1.00	1.17	72
	4.78 b/	2.30	1.43	6.05	0.26	14.82	NA	NA	NA	NA

Notes: a/ Central Statistics Office estimates.
b/ Ministry of Economic Planning and Development estimates.
c/ UNIDO team estimates.

Mauritius: estimated consumption of meat 1985 and 1990 — End Table 11

	1985						1990					
	Beef	Mutton and goat meat	Pork	Poultry	Venison	Total	Beef	Mutton and goat meat	Pork	Poultry	Venison	Total
						kg/head/y						
'High' range	5.276	2.706	1.821	6.444	0.272	17.019	6.026	3.091	2.080	7.932	0.311	19.440
'Low' range	4.901	2.514	1.692	6.450	0.253	15.810	5.205	2.670	1.797	6.850	0.269	16.791
						t/y						
'High' range	5 324	2 730	1 837	7 007	274	17 172	6 610	3 391	2 282	8 701	341	21 325
'Low' range	4 945	2 537	1 707	6 508	255	15 952	5 710	2 929	1 971	7 515	295	18 420

Source: UNIDO team estimates.

APPENDIX 4

Mauritius: prices of edible livestock products in 1977 and 1980 and price indices in 1980 (1977 = 100)

End Table 12

Livestock product	Unit	1977 Rs	1980 Rs	1980 1977=100
Beef:				
fresh	500 g	12.03	18.75	159
frozen topside	550 g	7.00	16.00	229
Mutton:				
frozen: boneless	500 g	5.59	9.43	169
Goat:				
fresh	500 g	9.36	15.58	166
frozen: boneless	500 g	6.67	12.90	193
Poultry meat:				
frozen	500 g	6.75	9.75	144
Venison	500 g	10.00	18.00	180
Milk:				
fresh	1 litre	1.25	2.50	200
condensed	340 g	2.82	3.72	132
powder	454 g	3.76	6.61	176

Source: Central Statistics Office.

Mauritius: land utilisation | End Table 13

Category		Ha	As % total
Land under cultivation		97 823	52.5
Sugar cane	86 716		
Other crops	11 107		
Grasslands a/		7 446	4.0
Forest		56 025	30.0
Crown b/	20 459		
Pas Géométrique c/	422		
Mountain reserve	3 799		
River reserve	2 744		
Private	28 601		
Other (reservoirs, swamps, rocky areas roads, built-up areas etc)		25 190	13.5
Total		186 484	

Notes: a/ Estimate from FAO/UNDP Land and Water Resources Survey.
b/ Crown forests include scrubland as well as 10 522 ha of forest plantation.
c/ Pas Géométrique is a narrow belt of land along the coast.

Source: Ministry of Economic Planning and Development.

APPENDIX 4

APPENDIX 5

BY-PRODUCTS: LIVESTOCK FEEDS

CONTENTS

CONTENTS (cont

SUMMARY

1. Mauritian experience in the use of sugarcane by-products in livestock rations is reviewed:

   a) Molasses fed at high intake levels to cattle has not produced consistently good results. It is suggested that molasses could be mixed with the roughage ration (ie cane tops, fresh or ensiled), and fed at higher than conventional levels to non-ruminant livestock;

   b) Bagasse will not be used in quantity as a roughage feed unless a method of upgrading its nutritive value can be shown to be economic;

   c) Sugarcane tops are the most underutilised by-product. Good quality cane top silage can be made, but economic methods of field collection require investigation;

   d) Filter mud nutritive value has been investigated in the past. Its use as a wet material and as a source of trace elements should be further investigated;

   e) Vinasse could be used to produce either condensed molasses solubles or feed yeast but it is not recommended that these options be investigated as other methods of using vinasse are more energy efficient;

   f) The extraction of Leaf protein and protein from sugarcane juice have both been investigated to a limited extent. The extraction of protein from sugarcane juice would appear to be the more viable process and should be further investigated.

2. Methods of improving the nutritive value of roughage by-products (cane tops and bagasse), by using caustic soda or ammonia or by steaming are discussed and tentative costings made. The latter are such as to suggest that one or more of these methods could be viable and should be investigated.

3. Estimates of total feed use and feed requirements to 1990 are made. These suggest that the supply of sugarcane by-product roughages (bagasse and cane tops) will not be a constraint on livestock production.

4. The availability and use of feeds other than sugarcane by-products is considered. These include poultry manure, maize, maize stover and cobs, Leucaena leucocephala, oilseeds, wheat bran (if a flour mill is established) and forage.

5. A number of rations that include feeds available in Mauritius were formulated using least cost techniques. The results suggest that:

   a) molasses is the most economical source of feed energy available and should be utilised to a maximum extent;

   b) at cane top prices above Rs500 ($58)/t dry matter, caustic soda treated bagasse is competitive as long as the price of bagasse remains low; and

   c) there is scope for the use of least cost formulation techniques in designing the most economic feeding systems for livestock in Mauritius.

6. Projects for research and development of livestock feeds are suggested. They would be supervised by a livestock production expert, who would be responsible for their extension to the commercial sector; he would also advise the livestock producers in production techniques. Their total cost is Rs4 M ($0.4 M); of this Rs2.5 M ($0.25 M) would be to provide experts from outside Mauritius, hopefully under bilateral or multilateral aid programmes.

1. INTRODUCTION

1.01 One of the ways in which sugarcane and sugarcane by-products can be used is for feeding to livestock, particularly ruminant animals such as cattle, sheep, goats and deer. However, because of the limited present ruminant population in Mauritius the potential for use of by-products in this way is limited in relation to the total output from the sugarcane industry.

1.02 In view of the substantial amounts of cane and cane by-products available it cannot be said that there is an overall shortage of feed for the present or likely future ruminant animal population. The main consideration is whether suitable feeding systems can be developed to utilise the by-products profitably, either by sole use of them or by the addition of supplementary feed material.

1.03 Some of the by-products, such as cane tops and bagasse, are only seasonally available and methods and costs of conservation are important in maintaining continuous supplies throughout the year. Cane tops and particularly bagasse have low nutritive values and the feasibility of applying techniques for increasing that value needs to be assessed. The improvement in nutritive value has to be set against the cost of carrying out the treatments, and compared with the price of nutrients available from other feeds such as forages and cereals (maize).

1.04 In this Appendix the above aspects are discussed in greater detail. In most cases insufficient experimental and pilot scale data are available to carry out definitive appraisals but, on the basis of certain assumptions, indications of the likely value of different approaches are obtained. These should provide a basis for determining the factors to be considered in future investigational and commercial development programmes. The use of by-products forms an integral part of the overall feed industry and a brief review of this is included.

2. REVIEW OF EXPERIENCE TO DATE AND DISCUSSION OF POTENTIAL FOR FURTHER USE

Molasses

2.01 Current use of molasses for animal feeding in Mauritius is estimated at 6 000 t/y. A research programme aimed at increasing the utilisation of molasses in animal feeding, particularly for beef production, has been underway for some years. An FAO/UNDP consultant, Dr R Preston, has been advising the Government with regard to this programme as well as assisting with similar programmes in a number of other countries. Much emphasis in the work has centred on the use of high molasses diets for cattle fattening. Typically, cattle are fed up to 6 kg/d or more molasses in combination with around 3% urea as a source of nitrogen (for protein deposition), and minerals. Early studies on these diets in other countries indicated that a number of problems occurred, and daily liveweight gains were less than those anticipated from the nutrient content of the diet. Subsequent work has shown that the provision of supplementary protein (eg as cottonseed cake), and starch sources (eg maize) restored weight gains nearer to those predicted from the nutrient content. The interpretation of these results has been that such materials act as sources of "bypass" protein and starch, ie protein and starch which is not degraded in the rumen, but passes into the true stomach and intestine where they are broken down into their constituent amino-acids and glucose respectively. Further work has shown that Leucaena leucocephala (locally known as acacia) is an effective supplement to high molasses diets. This plant grows reasonably well in certain parts of Mauritius and is now cultivated on some estates.

2.02 Extension of this work to Mauritius has not produced such consistently good results as in other sugarcane producing countries. In some trials such types of diet have produced good growth responses, whereas in other trials the responses have been poorer. The reason for these differences has not yet been identified, but obviously the effect on profitability can be quite marked if cattle growth rates in the region of 0.5-0.6 kg/d are obtained compared with around 1 kg/d at other times. It is desirable to carry out research to try to identify the reason(s) for the inconsistent growth responses; since there appear to be no definite leads at present, such research would have to be of a long term nature.

2.03 In the meantime it would appear to be preferable to consider the use of rations with much lower molasses content than those described in para 2.01. Unfortunately, because of the nature of ruminant digestion it is not possible to use intermediate levels of molasses in rations with a normal fibre content since it is generally accepted that a molasses level above about 15-18% in the feed reduces the digestibility of the fibre component of the ration. The exceptions to this of course are the high molasses rations mentioned in para 2.01 where a small proportion only of fibrous material is included to maintain rumen tone and function.

2.04 Molasses can be incorporated in the diet in a number of ways including for example:

a) The provision of restricted amounts of liquid molasses or molasses/urea mixes in troughs. This is the simplest and cheapest procedure but it is not certain whether it stimulates the intake of roughages to the same extent as methods c) and d) below.

b) Feeding molasses and urea in the form of solid blocks or "licks". These are placed in the fields where animals are grazing and they may need some form of protection from rain. They are frequently used as a supplement to poorer quality roughages when they are reputed to increase the digestion and hence intake of such materials. In Mauritius they could be used as a supplement for rough grazing, or for cane tops especially in situations where these can be grazed in the field. Various formulations for blocks are available. Typically they consist of up to 45% molasses with some ground cereal, oilcake, urea, salt and other minerals, plus vitamins as required. Although they are commercially produced in high pressure presses, suitable formulations can be manually tamped into cardboard boxes or other suitable moulds. Blocks can be stored and handled more easily than liquid molasses mixtures.

c) Mixing molasses/bagasse (paras 3.35-3.36) into a dry diet, especially with other supplementary feeds in addition to forages and/or other roughages.

d) Mixing the molasses into a complete ration, or the roughage part of the ration, for example chopped cane tops. Ultimately this could involve the use of special equipment available for complete ration mixing and feeding. In the meantime manual procedures could be considered. In using this procedure under tropical climatic conditions it is important that the complete feed is freshly mixed at each feeding time to avoid the possibility of fermentation.

2.05 There has been increasing interest in recent years in the use of a higher percentage of molasses in pig and poultry feeds. Where feeds for these livestock are pelleted it is common practice to add 2.5-5% molasses, particularly as a pelleting aid, but recent research has shown that up to 30% can be incorporated in pig grower feeds, and up to 20% in poultry feeds, though such feeds cannot be pelleted. At higher levels molasses tends to have a laxative effect, and this may necessitate some alteration in management systems. It is already being used in some pig feeds in

Mauritius at a level of 10% or more and there would appear to be scope for increasing its use in this way. Further research into these possibilities is required.

2.06 Projections of the maximum potential usage of molasses as animal feed in Mauritius are as shown below; however it is unlikely that these amounts will be utilised.

		Current use 1980 (t)	Potential Use 1985 (t)	1990 (t)
Cattle:	High level a/	N.A.	38 574	61 869
	Low level b/	N.A.	15 360	21 960
Pigs c/		N.A.	1 696	2 106
Poultry d/		N.A.	4 287	4 954
Sheep, goats, deer e/		N.A.	11 644	14 268
Total	High	6 000	56 201	83 197
	Low		32 987	43 288

a/ Beef cattle, 6 kg/head/d; dairy cattle 1.5 kg/head/d throughout the year. Based on projections for cattle numbers (paras 6.07-6.08, Appendix 4).

b/ All cattle, 1.5 kg/head/d throughout the year.

c/ 15% of all pig feed. Calculated from data in End Table 2.

d/ 10% of all feed. Calculated from data in End Table 3.

e/ Assumes total numbers 142 000 in 1985, 174 000 in 1990: overall allowance of 0.225 kg molasses/head/d throughout the year.

Bagasse

2.07 Although surplus bagasse has been available it has only been used to a very limited extent for feed purposes in Mauritius. Untreated bagasse has a very low nutritive value as indicated by its composition. Fresh bagasse contains 46-52% moisture, 43-52% fibre and 2-6% solubles, mainly sugar 1/. Limited investigations have been carried out on possible methods of improvement, such as alkali and steam treatment, but these do not appear to have advanced sufficiently to be used as a basis for an assessment of

1/ Antoine, R (1979). Present situation on the utilization of by-products of the sugar industry in Mauritius. UNIDO Workshop, Vienna March 1979. UNIDO: Vienna.

their possible commercial application. An alternative way of utilising some bagasse is to dry and sieve it and use the finer (pith) fraction as a carrier to prepare a molasses/pith mixture in meal form. This is possible because bagasse pith has a high absorptive capacity for molasses (greater than any other commonly available raw material). Urea as a source of nitrogen together with other supplements including minerals and vitamins can be incorporated into the mixture as required.

2.08 The mixture can be used to supplement roughages, cereals and/or other raw materials incorporated in cattle diets. Favourable results from feeding an imported molasses/bagasse mixture have been reported by one sugar estate. The cost and value of such mixes would depend very much on the cost of drying the bagasse, and they have to be compared with alternative ways of incorporating molasses into feeds, eg with chopped cane tops. Amounts of bagasse which could be used in this way seem likely to be small, no more than 5 000-10 000 t/y.

2.09 It seems unlikely that there will be any significant increase in the amount of bagasse used for feed purposes unless one of the methods of upgrading its nutritive value can be shown to be economically worthwhile. Such possibilities are discussed in greater detail, in conjunction with the use of molasses/bagasse pith mixes, in Section 3.

2.10 In terms of non-feed uses, dried bagasse could be used as litter in deep litter poultry houses, since it is understood that the wood shavings currently used are becoming less readily available. Bagasse or bagasse pith would be preferred to wood shavings if the litter is to be subsequently used as a feed ingredient (paras 6.01-6.04).

Sugarcane tops

2.11 At harvesting the tops are cut from the cane and left on the fields. A typical analysis of such unburnt tops is given below. The effect of burning or the use of chemical ripeners (glyophosphates) on the composition is not known.

	%
Crude protein	5.0
Crude fibre	35.0
Ether extract	2.8
Ash	7.3
Nitrogen Free Extract	49.9

Source: MSIRI.

Estimates of the yield of cane tops are very variable but on the basis of measurements undertaken at the team's request on two sugar estates (Médine and Britannia) the tops were found to comprise 13-19% of the total weight of cut unburnt cane and 16-26% of burnt cane. Assuming an average value of about 17%, the estimated weight of tops corresponding to 6.217 M t of milled cane is about 1.3 M t, fresh weight (para 3.07, Appendix 1).

2.12 Some planters prefer to leave cane tops on the fields for fertiliser and mulch value; in the dry areas in particular the result is an improvement in cane yields. Traditionally a proportion of the tops has been collected by small cowkeepers for feeding to their cattle during the harvesting season. The tops are manually selected, all dead leaves (trash) being discarded, and carried to the cow stalls. The decline in the number of cows owned by small cowkeepers has meant a corresponding decline in this form of cane top usage.

2.13 More recently, with the development of beef cattle herds by some sugar estates, interest has developed in larger scale use of cane tops. The methods of collection and utilisation then become important because they can represent a high cost in relation to the nutritive value of the material. Manual methods of collection are not relevant because of the high cost, and mechanical methods need to be developed. Mechanical cane loaders are becoming widely used and they also load tops on to trucks. On Savannah estate trucks used to transport cane are occasionally diverted to transporting cane tops. The tops are then chopped with a forage harvester or other chopper at the feedlot prior to feeding. One alternative is to collect the tops with a forage harvester, as at Union, which delivers them in chopped form into a following trailer.To avoid problems from soil compaction in the growing crop, this technique is only used to collect the tops from the final ratoon. At Constance a baler is being used for collecting cane tops.

2.14 Such methods are applicable to the use of tops in the fresh state. For conservation the chopped tops need to be ensiled, or dried and baled in the same way as hay. In the higher rainfall areas the latter method may be unfeasible, while even in the lower rainfall areas problems may arise from the slow drying rate of the apex of the stem which is cut off with the leaves attached. The latter problem might be overcome by the use of preservatives, of which the first choice would be ammonia since this could also increase the nutritive value of the tops (para 3.16-3.26).

2.15 The most straightforward procedure is to ensile the fresh tops, as at Medine estate. Some molasses is normally included to assist the production of lactic acid by fermentation; this is the basis of this method of conservation. The use of alkalis or urea might also be considered. These possibilities are discussed in greater detail in Section 3.

2.16 The maximum projected potential use of cane tops for animal feed is estimated to be as follows:

	Current use 1980 (t'000)	Potential use 1985 (t'000)	1990 (t'000)	% Total cane tops 1990
Cattle a/	75	196	281	21.6
Goats b/ Sheep b/ Deer b/	19	85	104	8.0
Total	94	281	38.5	29.6

a/ Compiled from livestock projections, (paras 6.07-08, Appendix 4). Daily allowance equivalent to 21 kg fresh cane tops/head throughout the year.

b/ Assumes total numbers 142 000 in 1985, 174 000 in 1990, overall allowance of 1.65 kg fresh cane tops/head throughout the year.

It is extremely unlikely that these usage rates will be achieved, nevertheless they represent less than one third of the total available.

Filter mud (filter cake, press cake, scum)

2.17 Filter mud is the by-product obtained at the juice clarification stage. Cane juice from the crushers is heated to 105°C and lime added leading to the precipitation of many of the non-sugar components such as protein, organic acids, waxes and phosphates together with entrained small particles of soil and fibre. The sediment, or mud, is then removed before the clarified juice is passed to the concentration stages. In the past it was separated directly by a filter press, but a decantation and washing stage has been introduced which reduces the residual concentration of sugar in the mud.

2.18 Data reported on the composition of filter mud from Mauritius are shown in End Table 1.

2.19 The material is normally returned to the cane fields as a fertiliser, but because of its favourable crude protein content it has received attention as a possible animal feed ingredient, and is being used to a limited extent in some countries in this way. Early work in Mauritius 1/ suggested that dried filter mud was a valuable material for feeding to animals including rabbits, pigs and poultry but other trials indicated problems with rabbits in terms of palatability and pigs also in terms of poor feed conversion ratios. Digestibility trials with sheep gave disappointing apparent digestibility coefficients of 14% and 13% for the crude protein fraction of oven dried and air dried filter mud respectively, though higher values were obtained with goats. The following possible causes for the low digestibility of the protein were suggested:

a) precipitation of the protein from a strong solution of sucrose and reducing sugars at a temperature of 100°C and under slightly alkaline conditions causes denaturation of the protein;

b) coating of the protein particles with waxes prevents enzyme action in the digestive tract of animals; and

c) the high temperature used to dry the filter mud.

2.20 In 1969 an FAO/UNDP consultant, D A Miles, was employed to attempt to resolve the conflicting findings. As a result of his studies he recommended that "sugarcane scums do not justify development and exploitation as protein feed for animals" for a number of reasons including:

a) the very low digestibility and nutritive value of dried sugarcane scum (filter mud);

b) the relatively high cost per unit of its digestible crude protein;

c) the restricted amount of nutrient which the whole of the scum yield of the sugarcane factories provide;

d) the very large amount of bulk involved in relation to the recoverable protein and the associated practical difficulties; and

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1/ Staub, S and Darné, A (1962). The use of scums in livestock feed. Dept Agric, Mauritius.

e) the practical certainty that superior and cheaper alternative sources of animal protein feeds will become available in the near future, in quantities sufficient to provide for all foreseeable development and expansion of the livestock industry.

2.21 As a result of these recommendations little further work was done; this was unfortunate because in retrospect superior and cheaper alternative sources of animal protein feeds have not materialised and are unlikely to do so in the foreseeable future other than from imports. Under item c) it was calculated that the total protein present in the mud was 4 500 t (cf 6 000 t elsewhere 1/, of which 750 t was digestible). This is not an insignificant amount (see para 2.35).

2.22 Fresh filter mud may have a moisture content of up to 85% giving a high drying cost. It is therefore appropriate to consider the use of the mud in the wet form, eg as an addition to ensiled cane tops. It was understood that the addition of mud to silage has been attempted by one sugar estate, but that the results have not been encouraging on account of poor palatability of the silage. The proportion of filter mud included is not known.

2.23 Apart from conflicting results on the nutritive value of the protein, the mineral and trace element composition appears to have attracted little attention. However the concentrations of certain trace elements (End Table 1) are exeedingly high in animal feed terms. For example, copper is present at 350 ppm (air-dry basis), and it is possible that high intakes of filter mud could induce copper toxicity in a final feed as the copper content should not exceed about 10 ppm on a DM basis.

2.24 It is possible that the mineral and trace elements in the mud have a low availability in which case above average levels could be tolerated. This information would need to be established before the mud could be considered as a major component of feeds irrespective of the value of the protein.

2.25 Palatability problems encountered with feeding filter mud have been attributed to the waxes present. However, if the mineral and trace element concentrations (End Table 1) are typical it is highly likely that they would be a contributory, if not the major factor affecting palatability. These high concentrations might cause a reduction in the activity of the rumen microflora and thus reduce the digestibility values of the feed.

1/ Parish, D H (1960) Protein from sugarcane. Nature (Lond.) 188, 601.

2.26 It is important to establish by further analyses whether the mineral and trace element concentrations quoted in End Table 1 are typical, and if so to investigate the possibility of using the dried mud at low levels (say 4-5% of the diet DM) as a source of these elements. In the case of direct use for cattle this would imply a usage rate of around 10% on a wet weight basis of mud, added to a complete diet based on chopped cane tops, or for inclusion in cane top silage. Reports that deer consume limited amounts when offered on a free access system suggest that it may be fulfilling such a function. Use of the mud for this purpose would have a more significant impact if it could be shown to be suitable for use in poultry and pig feeds but it would need to be used in a dry form, thus incurring the costs of drying. If its use proved to be feasible in these ways it could substitute at least partially for current imports of mineral and trace element supplements.

Vinasse

2.27 Vinasse is the liquid residue of the distillation of alcohol produced by fermenting molasses. It consists mainly of a solution of the mineral salts from the molasses, together with other residues and suspended yeast. A typical analysis is as follows:

	%
Dry matter	7-10
	on DM basis:
Ash	29.0
Sugar (reducing)	11.0
Crude protein	9.0
Volatile acids	1.5
Gums	21.0
Combined lactic acid	4.5
Other combined acids	1.5
Glycerol	5.5
Waxes, phenols, etc	17.0

Source: Paturau J M (1969). By-products of the cane sugar industry. Elsevier: Amsterdam.

2.28 A number of methods of disposing of this material have been considered in Appendix 6A, one possibility being its use for feed purposes. Although the liquid can be fed to cattle, either alone or absorbed in a carrier such as bagasse, the more usual approach for this purpose is to condense it to give 'condensed molasses solubles', or to dry it. In these forms it can be used as an alternative to molasses, or in combination with molasses, for feed use mainly for cattle. The main constraint to this use is the high cost of condensing or drying since the dry matter content of the vinasse is low. In paras 10.02-03, Appendix 6A, it is shown that the net energy generation is negative if vinasse is condensed and that the energy return on capital is very low. Consequently it is not proposed that this option should be explored.

2.29 An alternative procedure is to separate the suspended solids (consisting mainly of yeast) by centrifuging and to dry this fraction, thus producing a dried yeast preparation. The yeast must be dried at a high temperature (130°C) and is usually done in roller drums. The yield from a 107 000 ℓ/day distillery would be of the order of 6 500 kg/d, or 871 t over 134 working days. Such material would be expected to have a crude protein content of about 30%, and its value therefore would be about two thirds that of soyabean meal.

2.30 The local feed milling industry would be able to absorb this quantity of material given a competitive price. The equipment necessary for centrifuging and drying the sediment would be similar to that required for recovery of precipitated protein from cane juice (para 2.35). However, the reasons given in para 2.28 for not producing condensed molasses solubles also apply to any proposal to produce dried yeast from vinasse.

2.31 In some countries feeding operations are adjacent to the distilleries and the vinasse is sedimented and decanted for direct feeding to pigs or other animals.

Fodder yeast

2.32 Fodder yeast (*Torulopsis utilis*, *Candida arborea*, *Candida utilis*) can be obtained from fermentation of molasses. It is used as a source of protein especially in compound feeds. With a protein content of about 50%, it is approximately equivalent to soyabean meal in value. Since feed milling activities are relatively well developed, and depend entirely on imports of feed raw materials specially for pig and poultry feeds, a market exists for such a product in Mauritius. Over 5 000 t of oilseed meal were imported in 1980 (End Table 2, Appendix 4). Fodder yeast, if available, could substitute for a part of this.

2.33 The main criterion in determining whether production of fodder yeast should be considered is whether it can be produced at a cost competitive with imported soyabean meal. Recent quotations for the cost of a plant to produce 15 t/d fodder yeast at 92% DM (ie about 4 500 t/y based on 300 working days) have been of the order of

Rs99.6 M ($9.72 M). The yield of yeast is around 250 kg/t of molasses which would be valued at approximately Rs1 373 ($134) in comparison with the current cif soyabean meal cost of Rs1 035 ($101).

2.34 It is considered that these factors indicate that the production of fodder yeast is unlikely to be a viable proposition. Further information on the production of fodder yeast is provided in paras 4.01-0.4, Appendix 6B.

Protein from sugarcane juice

2.35 Investigation by MSIRI has shown that cane juice from the mills contains about 0.1% crude protein. Experiments were carried out to devise suitable methods of recovering some or all of this protein. It was shown to be possible to produce a material containing about 25% crude protein by heating the cane juice to 90°C, and then centrifuging it. Although the concentration of protein in the juice appears low, the overall yield of protein would be 6 000 t, or more than twice the protein currently imported in oilseed meals. In terms of equivalent amounts of protein this would be worth more than 12 000 t of soyabean meal (50%), which at the current price of Rs4 141/t ($404) cif Port Louis is Rs49 M ($4.8 M).

2.36 The costs of milling the cane and heating the juice are incurred in sugar production, because the juice is heated before clarification. The main additional cost likely to be involved therefore is that of a continuous centrifuge. A continuous bowl centrifuge with intermittent cake discharge, and a juice throughput in excess of 8 t/hr, is estimated to cost Rs1.54 M ($150 000). Electricity requirements are 20 kWh. Approximate costs are therefore:

	Rs/hr
Depreciation (10% per year over 134 days x 20 hrs)	57
Electricity 20 kWh @ Rs0.96/kWh	19
	70
Yield equivalent to 16 kg soyabean meal @ Rs4.1/kg	66

2.37 Unless the price of soyabean meal (and other oilseed meals) increases significantly above current levels, it seems unlikely that the cane protein could be produced more cheaply in this way, but it could give rise to a saving in foreign exchange. It is considered therefore that further studies would be justified to obtain more information on the yields and quality of protein that can be obtained with appropriate pilot scale equipment.

Leaf protein

2.38 In common with other leaf proteins the amino-acid profile of sugar cane tops is acceptable, especially in terms of lysine content. A limited amount of work has been undertaken by the University of Mauritius School of Industrial Technology and the data from this work have been used for the yield estimate given below.

2.39 Extraction of protein from many crops has received a good deal of attention in recent years. Although technically feasible, the economics of the process remain marginal even for high protein forages like alfalfa which contain around 22% crude protein (DM). The crude protein content of cane tops is around 5%. In the work referred to above it was reported that after grinding and pressing the leaves, a yield was obtained of approximately 4 kg dry leaf protein concentrate containing 49.2% crude protein/t tops.

2.40 In animal feed terms the yield of leaf protein concentrate/t cane tops in these trials corresponds to approximately a similar weight of soyabean meal. Even if 80% of the protein could be extracted, which is unlikely, that from 1 t of fresh cane tops would be equivalent to about 40 kg of soyabean meal, or Rs166 ($16). This return cannot possibly cover the cost of processing.

3. TREATMENT OF BAGASSE, SUGARCANE AND SUGARCANE TOPS

Properties of cellulosic wastes

Cellulosic wastes are principally sources or potential sources of energy for livestock as their crude protein contents are normally very low. Their gross energy contents (approximately 16-18 MJ/kg) are very similar to those of other feed raw materials such as forages or even cereal grains, but the limiting factor in their use as animal feed is their low digestibility even for ruminant animals such as cattle. The low digestibility is attributed to the effect of constituents such as lignin and silica which form a barrier between the cellulose and digestive enzymes. A considerable amount of research is now being carried out to develop methods of improving the digestibility of cellulosic wastes because of the large quantities that are available in many countries. The technical feasibilities of several methods have already been established; the constraint in many cases is that the cost of treatment outweighs the increased returns available from the treated product.

3.02 Although methods available have received some attention in Mauritius insufficient investigational work has been undertaken to permit an evaluation of commercial parameters. This section assesses the likely viability of the various methods. In the first case this involves a comparison of the value of a material before and after treatment in relation to the cost of treatment, while the implications in terms of feed formulation will be discussed in Section 5.

3.03 The methods discussed below are applicable in principle to bagasse, cane tops and to whole cane. There are some differences in the detailed processes for each type of material, and these are mentioned where relevant. Since some bagasse and most cane tops are currently underutilised, it would appear logical to concentrate on them initially, though it may be economical in some circumstances to consider whole cane. This is discussed in more detail in Section 5.

Treatment with caustic soda

3.04 The most widely tested and adopted procedure to date in developed countries for improving the digestibility of cellulosic wastes is treatment with caustic soda (NaOH). There are three general types of approach to the use of caustic soda. These are:

a) the use of high volume dilute solutions for soaking roughages;

b) the use of low volume concentrated solutions or solid caustic soda followed directly by pelleting or other mechanical treatment; and

c) the application of caustic soda or solutions thereof to moist material followed by ensiling. Caustic soda and its solutions need to be handled with care and operators must wear protective clothing.

3.05 High volume dilute solutions for soaking The first process for improving the nutritive value of roughages was introduced by Beckmann in 1921. His method involved soaking straw in a large volume of dilute (1.5%) caustic soda solution, followed by draining and washing to remove excess caustic soda. This procedure is not very suitable for large scale operation, although modifications of it are still used in smallholder applications in some developing countries.

3.06 Low volume concentrated solutions of caustic soda More recent methods have depended on mixing concentrated caustic soda solutions with the cellulosic waste, after drying and/or grinding if necessary, generally followed by pelleting or rolling to ensure heating and/or close contact between the solution and the material. The caustic soda thus applied remains in the feed. This procedure is suitable for processing by machinery on various scales, and is being employed in many European countries and in North America for the treatment of cereal straws, cotton ginning waste and other wastes. Treatment of bagasse has to be considered as an extension of this work; as far as is known there is no operational commercial plant for caustic soda treatment of bagasse although the beneficial effect on the digestibility of bagasse has been established experimentally. The material to be processed should contain about 10 to 14% moisture content depending on the required storage. Bagasse from the sugar factory contains around 50% moisture, and it would need to be dried.

3.07 For the purposes of costing the process it is assumed that the output of an individual plant will be around 5 000 t/y. Smaller plants would cost less but the cost per tonne of finished product would be somewhat higher. If it is assumed that the above amount would need to be produced mainly during the harvesting season (134 working days duration) a plant capable of processing 33 t/day would be required. On the basis of one eight hour shift per day this corresponds to a nominal capacity of 5 t/hr.

3.08 Approximate costs of such a plant are given below, based on UK manufacturers' current estimates.

a) Capital costs Estimated ex-works UK prices:

	Rs '000
Dryer (single storage, rotary type)	1 337
Milling equipment	369
Measuring and mixing equipment	160
Pelleting and cooling equipment	612
Weighing and packing equipment	199
	2 677
50% for shipping installation etc	1 338
	4 015
Civil engineering including buildings, say 100 m^2	84
Total	4 099
	$400 000

b) <u>Running costs:</u>

	Rs/t
Caustic soda 4% = 40 kg @ Rs5.9 a/	236
Drying cost b/	
(Evaporation of 0.9 t water per tonne product = 90 ℓ oil/t product at Rs3.56/ℓ)	320
Power requirements: 200 kW/hr	
40 kWh/t @ Rs0.96	38
Labour: say 4 labourers	
= 4 man days/33 t = Rs240/33 t	7
Depreciation: 10%/y on equipment	82
Maintenance, 2%/y on equipment	16
Total	699
	$68.20

a/ The price is based on information provided by Mauritius Oil Refiners Ltd.

b/ The drying cost might be considerably reduced if flue gases from the sugar factory are used.

Addition of caustic soda followed by ensiling

3.09 An alternative treatment of bagasse is to add a solution of caustic soda to the material and then to ensile it in the moist state. The subsequent heating assists the reaction with the caustic soda, and the high pH aids preservation of the silage. It is envisaged that caustic soda would be added to the fresh bagasse as it leaves the mill, either as a concentrated solution or as a solid, and the mixture transferred to silos thus avoiding the cost of drying. It would also avoid the cost of equipment for pelleting etc although a mixer would be needed for adding the caustic soda. Appropriate silo facilities would be required. More detailed assessment would be necessary to determine whether the silos should be sited near to the bagasse output from the factory, or to the livestock feeding unit. In the case of cane tops or whole cane, it would be necessary for the material to be sprayed with the caustic soda solution and transferred to the silo, or it may be preferable to chop and mix them with caustic soda and then ensile.

3.10 An approximate estimate of the costs of plant to process 10 000 t/y bagasse are:

a) Capital costs

	Rs
Mixing and measuring equipment	
Mixer 2.5 t/hr	160 000
Augers etc	80 000
Silo (local construction cost; say 1 000 t concrete, 1 400 m^3 a/, 2 m high ie 700 m^2 @ Rs 140/m^2	98 000
	338 000
	$32 975

a/ Based on density of 700 kg/m^3.

b) Running costs a/:

	Rs/t
Caustic soda at 3% of DM (1.5% at 50% moisture content) 15 kg @ Rs5.9/kg	89
Labour, 3 hr/t	21
Use of tractors, loaders etc, 1 hr/t	21
Depreciation 10% of total cost over 2 500 t/y	14
	145
	$14.15

a/ Costs of collection of cane tops and transport have not been taken into account because they would be incurred in any case if cane tops were to be used for feeding.

This sum represents the cost of treating fresh bagasse which containing 50% DM. On a DM basis the cost is therefore Rs290/t ($28.29). For cane tops at 30% DM the cost of caustic soda would be Rs59/t ($5.77), giving a total cost of Rs167/t DM ($16.26).

3.11 The estimated cost of treatment in this way is considerably lower than the previous method, which incurs a heavy cost for drying. Without the drying cost the difference between the two methods is small, though still in favour of the ensiling procedure. The latter requires considerably less capital expenditure.

3.12 The costs of treatment have to be set against the improvements in nutritive value, which are assessed further in Section 5. However, if it is assumed that treatment increases the metabolisable energy (ME) concentration by say 2.25 MJ/kg (from 5.50 to 7.75 MJ/kg DM) for bagasse the treatment cost per MJ incurred in the ensiling procedure corresponds to:

$$\frac{\text{Cost of treatment Rs/kg}}{\text{Increase in MJ/kg}} = \frac{\text{Rs}0.29}{2.25} = \text{Rs}0.128/\text{MJ} \quad (\$0.013)$$

This can be compared with the cost of energy from the untreated cane tops:

$$\frac{\text{Cost of collection Rs/kg DM}}{\text{MJ/kg DM}} = \frac{0.5}{8} = \text{Rs}0.062/\text{MJ} \quad (\$0.006)$$

or with domestic maize at Rs2 300/t

$$\frac{\text{Maize cost/kg}}{\text{MJ/kg}} = \frac{2.3}{12} = \text{Rs}0.208/\text{MJ} \quad (\$0.02)$$

(This makes no allowance for the significant value of the crude protein in maize).

Treatment with ammonia

3.13 The improvements in nutritive value which could arise from the treatment of bagasse and cane tops (including trash) with caustic soda are indicated by an increase in vitro digestibility of bagasse from 32.0-50.1%.

3.14 In addition to caustic soda, other alkalis have been used to increase the digestibility of cellulosic wastes. Calcium hydroxide (limewater) has been used, but current emphasis is towards the use of ammonia either in liquid or gaseous form. Although in general this produces a slightly lower increase in digestibility than caustic soda, it offers certain advantages. The nitrogen content of most treated materials increases due to reaction with a proportion of the ammonia, while there is no residual high concentration of a metal ion to be eliminated by the animal's body.

3.15 The method of application is also simpler in some cases. Because the ammonia can be applied where appropriate in a gaseous form, it dispenses with the need for a grinder or a mixer. As with caustic soda, most work on the commercial application of ammonia treatment has been with cereal straws, and its potential application to bagasse and cane tops has to be discussed from analogy with straw. Some early experimental results with bagasse did not give particularly favourable results especially as residual ammonia depressed intake of the treated bagasse. However similar responses have also been recorded with straw on some occasions, and with improved experience and equipment these have not proved to be insurmountable problems. The purpose of the present review will be to attempt to assess potential costs and benefits of treatment in order to indicate whether further investigational work would be justified.

3.16 In terms of safety, ammonia treatment is preferable to caustic soda treatment at the small farm level. This is especially so because it has been shown that urea can be used to generate ammonia in ensiled cellulosic waste; many wastes contain the enzyme urease which hydrolyses urea to ammonia. This activity can be increased where appropriate by the addition of available legumes which have high urease activities. Urea is normally readily available as a fertiliser, and is relatively harmless to humans, although care must be taken to ensure that the final product does not contain too much urea because of its known toxicity to ruminants in excessive doses. At the smallholder level it is likely to be most applicable to the treatment of cane tops. Because of its texture, bagasse would be less suitable.

3.17 Ammonia treatment could be applied on a larger scale to bagasse or to cane tops at sugar factories for feeding to livestock on the sugar estates; in the case of bagasse it could be done at a livestock feed mill.

3.18 The cellulosic waste would be enclosed in an airtight envelope and a given amount of gaseous ammonia injected into the envelope. The material would then be allowed to stand for a prescribed period of time before the container is opened and any excess ammonia is aerated off. In one procedure bales of bagasse would be stacked on a polythene sheet and covered by another polythene sheet well weighted and sealed at the edges. A prescribed amount of ammonia gas would then be injected through a special valve, the valve would be closed, and the stack allowed to stand for about 28 days at ambient temperature before being opened and used for feeding. On the sugar estates this method would appear to be most applicable to dried cane tops. In order to compact them adequately for stacking and covering, baling would appear to be essential either on collection in the field, or with a stationary baler at the livestock unit. This procedure would appear to be less applicable to bagasse. Loose bagasse is very bulky and would be difficult to stack economically. Some bagasse is baled in Mauritius but the bales are compact and there are doubts as to whether ammonia gas would permeate them adequately. The use of bagasse pellets (Appendix 7A) for treatment with ammonia may merit consideration; although the pellets may be dense, they offer a large surface area and the distances which the ammonia must permeate are small.

3.19 As with caustic soda it is possible to add ammonia to moist materials and maintain them in closed containers. As well as reacting with the material to improve digestibility the ammonia acts as a preservative. This technique has been applied to the preservation of green oats for example, and could be tested with green sugar cane tops.

3.20 One of the considerations which has not yet been properly resolved in this approach is the extent to which residual ammonia in the moist material might affect its intake by the animal, since a reduction in intake of certain other types of feed (eg grass silage) has been associated with elevated levels of ammonia. Such an approach would eliminate the cost of drying cane tops (and trash) or bagasse which is the most expensive stage of the processes described earlier, but would necessitate the construction of suitable silos and the consequent costs.

3.21 An alternative industrial approach to ammoniation of cellulosic wastes is available. This involves equipment where the material is treated batch wise in a closed container at elevated temperature (thermoammoniation). As might be expected a higher temperature speeds up the reaction and reduces the dwell time, in this case to around 24 hr. Commercial equipment for carrying out this treatment on bales of straw is available on the market. A typical example enables the treatment of 700 kg at 95°C per 24 hr. The product is prepared on a daily basis and used directly for feeding.

3.22 Its application to cane tops and bagasse would be subject to the same comments as those in para 3.21, except that it might also be applicable to baled fresh cane tops. Application to loose bagasse would need to be investigated thoroughly; it could avoid the need for drying the bagasse during the milling season, while stored pellets could be used for treatment out of season. Special precautions, including the use of protective clothing, would be required if annydrons ammonia was used.

3.23 Anhydrous ammonia is imported into in Mauritius for fertiliser manufacture, and the price used is based on this source. The exact mechanism for transport of the ammonia from the dock or fertiliser plant would need to be determined, but is assumed to be by tanker.

3.24 The capital costs for the treatment of bagasse with ammonia are:

a) Cost of equipment (based on Danish equipment as a model):-

	Rs
One automatic ammonia treatment plant (internal capacity 12.5 m^3) to take 700 kg material approximately:	78 620 fob a/
or:	118 200 cif
	($11 534)

a/ fob price in UK

b) Estimated running costs:

	Rs/t
Ammonia 3% @ Rs3 025/t a/	90.75
Running cost - electricity 5.77 kW $(5.77 \times \frac{1\ 000}{700} \times 15$ kWh/t max)	
= 123.6 kWh @ Rs0.96	118.66
Use of tractor and loader 1 hr/batch b/	20.00
Purchase or hire of tank for ammonia c/	87.78
Depreciation (20% over 300 t)	78.80
Total	395.99
	$38.53

a/ Based on information supplied by fertiliser factory.
b/ Assumed available on site.
c/ Based on UK cost.

Steaming

3.25 Another method of increasing the digestibility of cellulosic wastes such as bagasse is by steaming. Some exploratory work on this type of treatment has been carried out in Mauritius but the method does not appear to have been fully assessed at pilot/commercial plant scale. Generally speaking, in the past the technique has not received much investigation for commercial use with straw and other agricultural waste products because the improvement in digestibility is often less than that obtained by alkali treatment, and because the cost of steam generation by conventional methods and the subsequent drying are too expensive in relation to the improvement obtained. Also, in experimental work with various wastes, best responses in digestibility have been obtained at high pressures and temperatures (eg around 14 bar A at 198°C). Such conditioning create considerable engineering problems in operating the treatment at pilot/commercial scale, though these would be less in sugar factories than elsewhere.

3.26 Suitable equipment is reported to be available from Canadian manufacturers and a plant is in commercial operation in Florida for the treatment of bagasse.

3.27 Estimates of the cost of steaming The following estimates are tentative:

a) Capital cost The cost of plant claimed to process in excess of 5 t bagasse/hr operating at steam pressures of the order of 20-27 bar A at 300 to 400°C is quoted at approximately C$1 M, (Rs8.5 M, US$830 000) to which would be added costs for shipping and installation of about 70%, giving a total capital cost of Rs14.5 M ($1.4 M).

b) Running costs The principal running costs to provide an undried product would be steam, labour, maintenance and depreciation. The steam requirement is reported to be about 700 kg/t product DM. Assuming a steam cost of Rs.35/t this amounts to Rs24.5/t product DM equivalent to Rs12/t for bagasse at 50% DM. Therefore, costs based on a throughput of 30 000 t/y are approximately as follows:

	Rs/t
Steam, as above	12
Labour and miscellaneous costs	22
Maintenance 5%	24
Depreciation 10%	48
	106
	$10.34

c) Drying and storage costs are discussed elsewhere.

3.28 Improvements in DM digestibility of bagasse from 36% (raw) to 55% (treated) are reported. This corresponds to an increase in calculated ME value of 2.85 MJ/kg DM. The estimated cost of the increased ME content is therefore of the order of 0.07 Rs/MJ ($0.007), which compares favourably with estimated costs for other treatments (cf para 3.15). The main limitation with this procedure is the high capital cost, which suggests that such a plant could only be attached to one of the larger sugar factories. Nevertheless, it merits further study to ascertain its feasibility for Mauritius.

Ensiling with urea

3.29 The addition of urea to bagasse, cane tops and whole cane to improve their digestibility is an extension of the use of ammonia for this purpose. Urea is hydrolysed to ammonia and this together with heat generated from the ensiling process provides in effect ammonia treatment at an elevated temperature. Studies in other countries on the application of this technique are at an early stage, but promising results have been obtained in many cases. One of the problems associated with the technique could be urea poisoning in stock if animals receive excessive doses of urea. In some cases, work has been done on the use of cattle urine as a source of urea for the treatment of rice straw in small farms.

3.30 In many countries the attraction of using urea is that it is readily available at a reasonable price as it is used a fertiliser, whereas caustic soda and ammonia may not be available or may be too expensive. An additional benefit for smallholder use is that it is safer to handle than caustic soda or ammonia. However, in Mauritius these considerations do not apply. Both caustic soda and ammonia are readily available, and the safety aspects are most easily controlled when processing takes place on a rel[illegible]vely large scale as would be the case on sugar es[illegible] Moreover, the cost of anhydrous ammonia is in a s[illegible] range to that of urea, Rs3 025/t ($295) and Rs2 970/t ($290) respectively. The cost of addition of urea to say 4% of the DM is Rs119/t DM ($11.60) which is equivalent to about Rs39/t fresh cane tops ($3.81), or Rs59/t bagasse at 50% DM ($5.77). These costs do not appear to be unreasonable. The other main cost is that of the silo(s) to hold the material; this has been provided in previous paragraphs. It is suggested that any detailed investigations on the upgrading of roughages should include the addition of urea.

Molasses/bagasse mixes

3.31 Work on the use of molasses/bagasse mixes as a component of cattle feeds has been undertaken in a number of countries, and in some of them such mixes are commercially produced. Some interest has been shown in Mauritius and they are produced in South Africa and Reunion.

3.32 The mixtures generally consist of a high proportion of molasses absorbed in bagasse pith, and depend on the fact that bagasse pith is able to absorb two to three times its weight of molasses and still remain free flowing. Urea (as a source of nitrogen) and minerals can be added to the mix. The end product therefore provides a means of transporting and using molasses in solid as opposed to liquid form which can have advantages in certain circumstances. The bagasse pith acts as a carrier and as a source of roughage. There is some doubt as to the extent to which it is digested by the animal.

3.33 In order to prevent microbiological deterioration if the material is to be stored, the bagasse pith has to be dried to a low moisture content (approximately 6%) before the molasses is added. Drying costs are as shown in para 3.11. The dried bagasse is then mixed with the molasses and other additives in a special mixer before being bagged in moisture proof sacks (eg polythene, or polythene lined) or other suitable moisture proof containers.

3.34 Since this technique enables molasses to be handled as a solid rather than as a liquid it has advantages if it has to be moved over considerable distances. It avoids the need for special tankers or drums and for pumps. If in Mauritius molasses and bagasse are used for feeding purposes on the sugar estate which produces them, it would appear to be an expensive means of doing so mainly on account of the cost of drying the pith.

4. CURRENT UTILISATION OF FEEDS AND PROJECTED REQUIREMENTS 1985/90

Estimates of total feed use

4.01 The 1980 production of compound feeds was about 30 000 t (End Table 2). It is anticipated that in 1981 production will be less than in 1980 on account of the recession.

4.02 Compound feed production in 1979 was 28 641 t (23 895 t poultry; 3 692 t cattle; 2 t goats; 687 t pigs; 272 t horses; 54 t rabbit feed) 1/. There are three feed mills operating on a commercial basis; production data for 1980 are at End Table 2. Present capacity appears adequate for current production requirements.

1/ The Mauritius Chamber of Agriculture (1979-80) The President's Report, p31.

4.03 Cattle depend on fodder and supplementary feeds and receive little compound feed. It is estimated that the current annual requirement is of the order of 200 000 t fodder, and 23 500 t supplements (molasses, cereals, oil cakes etc).

4.04 Estimates of current usage of by-products are difficult to calculate because of lack of detailed statistics. Usage of molasses varies considerably, but it is likely that about 6 000 t/y is used for cattle feed. Estimates of usage of cane tops also vary within the range of 5-10% of total production. If it is assumed that about half the likely fodder requirement calculated above are cane tops this would represent around 100 000 t or about 8% of the total available tops.

4.05 Imports of feeds for all livestock (excluding hay and forage) in 1974, 1978 and 1980 were:

Volume: tonnes	1974	1978	1980
Prepared feeds	17 505	11 773	3 602
Feed ingredients	3 986	17 571	21 182
	21 491	29 344	24 784
Value			
Rs M	26	50	61
$ M	4.3	8.3	8.3

In End Table 2, Appendix 4 details of livestock feed imports are provided for the period 1974-80.

Estimates of feed requirements

4.06 Future feed requirements for some types of livestock are estimated to be as follows:

Livestock			Feed requirements t'000 1985	1990
Cattle a/	Forage		262 000	274 000
	Supplements (cereals, molasses, concentrates etc)		31 000	44 000
Pigs b/	Concentrate feeds	low	11 000	12 000
		high	11 000	14 000
Poultry:				
Broilers c/	Concentrate feeds	low	25 000	29 000
		high	27 000	33 000
Layers	Concentrate feeds	low	24 000	28 000

a/ Daily allowance 10 kg DM/head overall, 7 kg from fodder; 3 kg supplements (on DM basis). Values converted to fresh weight.

b/ Killing out 65%; Feed conversion ratio 4:1 overall.

c/ Dressing out 65% Feed conversion ratio 2.5:1 overall.

Assumptions made are indicated in the footnotes. The fodder requirements of cattle can be substantially met by cane tops.

5. OTHER FEED RAW MATERIALS

Poultry manure

5.01 Poultry manure has received considerable attention as a nitrogenous source in ruminant diets and is widely used in many countries. Some cattle feeders in Mauritius are now beginning to use it for this purpose, and because of its nitrogen content it should form a useful supplement to diets based on sugarcane by-products. The nutritive value depends on whether the droppings alone are available, as from layer cages, or whether they are from broiler houses and hence usually mixed with litter.

5.02 The yield of dry droppings is approximately 10 kg per layer per year, and 0.5 kg from each broiler. Current estimates of amounts available are 6 000 t, rising to 6 800 t/y in 1985 and 7 600 t in 1990.

5.03 Poultry manure/litter can be incorporated directly into farm mixed cattle feeds in a fresh, or air/sun dried form. For compound cattle feed production the dried form is essential. Drying is normally done artificially on a large scale, and the heat applied also sterilises the material. Use of fresh or air/sun dried forms have the disadvantage that they may be contaminated with pathogenic organisms eg Salmonellae, which can be transferred to the cattle (or other ruminants). This can be avoided by ensiling the litter alone or in combination with carbohydrate sources. Currently little value is placed on the material, but this will probably change as it becomes more widely utilised as a raw material for feeds.

5.04 The characteristic composition of poultry droppings and of the other materials in the section are shown in End Table 3.

Maize

5.05 Maize grain is invaluable as a supplement to roughage based diets. The current imported cost of maize is Rs2 720/t ($265). Present production costs in Mauritius are about Rs2 300/t which has been used in the feed formulation. The quantity of maize grain produced in 1980 was approximately 1 000 t, and this is expected to increase to 5 000 t by 1985. Its value lies in its high ME content, mainly as starch.

5.06 For use in cattle feed near the site of production it does not necessarily have to be dried after harvesting, as techniques for storage of moist grain are available, either by ensiling or by preservation with proprionic acid.

Maize stover and cobs

5.07 These residues from the harvesting and shelling of maize would form useful roughages for inclusion in cattle diets, being superior in nutritive value to other cereal straws, bagasse and possibly even cane tops.

5.08 Techniques for alkali treatment which have been discussed in detail in relation to cane bagasse and tops are equally applicable to stover and cobs.

5.09 Cobs can be ensiled if they cannot be easily dried for storage. Alternatively maize can be dried on the cob and the whole material could be ground for inclusion in ruminant feed; this assumes reasonable drying costs.

Leucaena leucocephala

5.10 L Leucocephala flourishes in certain areas of Mauritius. Work on cattle feeding has established its value especially as a supplementary feed for molasses based diets. Its high crude protein content makes it useful in ruminant feed combinations in places where it can be successfully grown.

5.11 If the leaves can be harvested and dried it might have a use in poultry feeds as an alternative source of carotenoid pigmenters to the use of alfalfa meal, which is currently imported. It is commonly used for this purpose in Southeast Asia.

Oilseeds

5.12 Reference is made elsewhere to the production or possible production of oilseed crops. These include groundnut, soya, and sesame. If significant quantities of these became available at economic production costs, they would be invaluable for the development of the livestock feed industry because of their protein content. This applies particularly to poultry and pig feed but also to ruminant feeds.

5.13 The Mauritius Oil Processing Company Limited possesses oil expression facilities capable of dealing with up to 3 000 t/y. At present it is being used to press 100 t copra/y.

5.14 There is considerable current interest in the utilisation of whole oilseeds in animal feeds. Even if production is too limited for oil expression to be worthwhile it might still be possible to consider their direct use in animal feed. Whole oilseeds have considerably higher energy contents than the corresponding deoiled cakes/meals, and this could be of value in supplementing low energy density rations.

5.15 The copra expeller cake is available for feed use. This should be a useful supplement for cattle feed and any expansion in its production would be useful.

Wheat bran

5.16 It is understood that feasibility studies for the installation of a flour mill have been undertaken. If this mill materialises, the wheat milling by-products produced will be another useful raw material both for use by the local compound feed industry, and for inclusion in cattle rations on the sugar estates and elsewhere.

Forage

5.17 There is some interest in forage production with limited trials being conducted at the Government livestock breeding stations, at Curepipe and Palmar. Legumes generally have better nutritive value than grasses, and young grass growth is better than mature grass. Forage usually represents the cheapest source of nutrients, especially if it can be grazed.

5.18 Pasture establishment costs very widely with location and conditions. If it is assumed that they are Rs5 000/ha ($488) and can be spread over five years, and that annual maintenance costs are Rs1 650/ha ($161), the annual cost is Rs2 650/ha ($258) for a yield of 10 t dry matter/ha/y 1/ with an ME value of around 8 MJ/kg DM is Rs0.033/MJ when grazed. This is less than one third the estimated cost of the energy obtained by alkali treatment of bagasse or cane tops. If fed on a cut and carry system the additional costs would have to be taken into account ie a similar cost to that of the collection of cane tops (para 3.15).

6. FEEDING SYSTEMS

6.01 Feeding systems for commercial production of poultry and pigs are relatively standardised; types of raw materials required and amounts of feed per unit liveweight gain can be calculated with a reasonable degree of certainty. Ruminants (cattle, sheep, goats) are capable of dealing with a much greater variety of raw materials, especially of roughages and by-products; though the processes which take place in the rumen and gut are still not well understood, especially where less conventional diets are used. It is not possible to deal with all the possible variations and any feed combinations quoted can only be regarded as examples of the possibilities available.

6.02 In developed countries, feed costs are normally considered to account for 80% of the production costs of livestock. If the feed cost is less it implies excessive costs of other inputs such as labour, management, transport.

6.03 Rations are normally formulated to meet estimated daily requirements of nutrients - protein (including non-protein nitrogen), energy, minerals and trace elements. Daily protein requirements cannot usually be met from roughages and other by-products alone and require supplementation with richer protein materials; and this is well understood

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1/ This is a conservative estimate of yield.

in Mauritius. However, it should not be overlooked that such materials generally also have low contents of ME; this seems less well appreciated. If one takes a conventional nutritional approach it is difficult to obtain high daily liveweight gains even using high intakes of such materials because their ME is not used as efficiently for growth as that from other feeds with a higher ME. The use of supplementary energy may therefore be as important as the use of supplementary protein. For example, in temperate climatic conditions it has been predicted that to maintain a daily liveweight gain of 1 kg/d or more for cattle weighing 250-450 kg a minimum ME value of 10 MJ/kg DM is required 1/.

6.04 With these factors in mind a limited amount of least cost formulation work has been done and the details are given in End Tables 4 and 5. It should be emphasised that some of the rations formulated are not necessarily suitable for feeding, but are intended to indicate the effect on ration costs of various combinations of raw materials. Formulations were done only in terms of crude protein and ME content. The basic assumptions on raw material composition and costs are shown in End Table 6. To enable simple comparisons of costs, the formulations have been carried out for an assumed fixed intake of 10 kg DM/d at the specified energy concentrations. The raw materials are those that are or could generally be available. It is understood that vegetable oils are imported to the local oil refinery at international prices. As a matter of interest therefore these have been included in the list of raw materials, since some are relatively cheap at the present time.

6.05 A number of rations were formulated as follows:

a) To assess the effect of varying ME concentrations, crude protein limits being kept constant. These are shown in formulations 1 to 3 End Table 3. No restrictions were placed on the inclusion rates of any of the feeds. All formulations were done on a 100% dry matter and 100% volume basis.

b) The same three formulations were re-run (Nos 4 to 6), but with the molasses restricted to a maximum of 15% (on a DM basis). The computer has responded by switching from bagasse to treated bagasse.

c) The effect of placing restrictions on other raw material inclusion rates to produce a more mixed ration were tested in formulations 7 to 9. Leucaena was restricted to 20% DM, and maize had a minimum of 10%.

1/ MAFF (1975) "Energy allowances and feeding systems for ruminants" MAFF Tech Bull 33. HMSO: London.

d) A minimum inclusion rate of 5% for cotton seed cake was added to the restrictions under (c). This leads to the inclusion by the computer of 18% treated bagasse in formulation 10 and 2% in 11.

e) Ranging, rejection and sensitivity tests were carried out on formulation 9 (End Table 4).

6.06 It would obviously be desirable to explore the cost structures for these systems in greater detail. However in the context of assumptions which have had to be made for the nutritive value and cost of sugarcane by-products, leucaena and dried poultry manure, the following indications are apparent:

a) They confirm, as expected, that molasses is the most economical source of energy, and that in cost terms there is a need to use as high inputs of molasses as possible consistent with acceptable daily liveweight gains.

b) In the cost and price specifications used here there is a fairly sharp cut-off point of around Rs500/t ($58) cane top dry matter. At prices above this, caustic soda treated ensiled bagasse could become competitive as long as the value of untreated bagasse remains low.

c) With the restrictions on some raw material inclusion levels as in formulations 7, 8 and 9, the ranging, rejection and sensitivity tests for formulation No 9 indicate:

i) the inclusion rate of cane tops would decline if the price exceeded Rs562/t DM ($55);

ii) the inclusion rate of Leucaena would decline if the price exceeded Rs980/t DM ($96);

iii) the inclusion rate of bagasse would not decline until its price exceeded Rs302/t DM ($29);

iv) the inclusion rate of maize would not increase unless its price was less than Rs1 126/t DM ($110);

v) treated cane tops would be included at a price of Rs743/t DM ($73), while treated bagasse would be included at a price of Rs470/t DM ($46);

vi) dried poultry manure would be included at a price of Rs730/t DM ($71). Such a price emphasises the potential value of this material.

d) Where a minimum inclusion level for cotton seed cake is added to the restrictions in formulations 7, 8 and 9, the computer includes 18% treated bagasse in the higher energy ration (formulation 10).

6.07 The methods of computation used are somewhat biased against treated bagasse and cane tops. Full least cost formulation involving net energy rather than ME values would place relatively greater value on the treated materials, while the preceding calculations make no allowance for possible beneficial effects on feed intake. Nevertheless it is clear that treated bagasse and cane tops are selected, or would be selected at or near the estimated cost of these materials. Therefore it is considered that further investigations should be carried out on the application of treatments with caustic soda, ammonia, or urea and the utilisation of the products in complete cattle rations.

6.08 There is considerable scope for the application of least cost formulation techniques in designing the most economical feeding systems for herds on the sugar estates.

7. TOPICS FOR FURTHER RESEARCH AND/OR FEASIBILITY STUDIES

7.01 Subjects which might justify further investigation have been indicated in the previous discussion.

Improved utilisation of sugarcane tops

7.02 Cane tops represent a considerable unused resource and one which could be relatively economic, especially where its collection and utilisation are mechanised. This aspect requires further research as also do the methods of handling and feeding the material. Certain sugar estates are already using forage harvester/choppers or balers for handling the crop and presenting it in a form convenient for feeding. The preservation of cane tops by ensilage for use when fresh tops are not available would benefit from further studies especially on the use of appropriate additives, and also the design of cheaper silos.

7.03 Project proposals involve:

a) purchase of 10 concrete experimental silos (circular, approximately 1 m diameter, 2 m high) to prepare silages for laboratory evaluation;

b) construction of 4 larger silos to prepare sufficient quantities of silage for feeding trials. These could be provided by estates cooperating in investigational work;

c) cost of various additives to be used in experiments;

d) machinery for collecting and chopping cane tops. This may possibly be met by agreement with Union to use their existing forage harvester.

Some development of appropriate machinery for harvesting cane tops may be involved for which an input by an agricultural engineer would be required;

e) manpower requirements (1st phase):

i) for laboratory ensilage and evaluation - 12 man-months (internal);

ii) for feeding trial work - 6 man-months (internal);

iii) agricultural engineering consultancy - 3 man-months (external).

Treatment of bagasse and sugarcane tops

7.04 Assessment of the costs of these processes in relation to increase in nutritive value suggest that initial emphasis should be given to investigations on the use of urea and of ammonia for the upgrading of bagasse and of cane tops. Treatment with caustic soda is more expensive and should receive a lower order of priority. The use of urea and/or ammonia in conjunction with ensiling thus avoiding the cost of drying etc seems likely to be the most economical approach.

7.05 Proposals for such work would include:

a) Using silos to investigate effects of treatment of bagasse and cane tops with urea and ammonia; analytical work on products; preparation of sufficient quantities of best products for feeding trials with cattle; 2 man-years.

b) To purchase and instal a treatment unit for thermo-ammoniation (preferable: steam heated; design may require investigation) and carry out trials. Baled cane tops and/or baled bagasse should be exported from Mauritius to UK or Denmark for initial trials;

24 man-months (internal);
1 man-month consultancy (external).

Feeding systems for cattle

7.06 The research needed on methods of handling, treating and storing bagasse or sugarcane tops needs to be related to studies on optimal feeding systems for cattle utilising these materials. More emphasis is needed on a wider view of the development of feeding programmes rather than attempts to maximise the utilisation of any particular material *per se*. The application of general principles of animal nutrition as discussed in Section 5 should be of assistance in obtaining higher productivity; for example an increasing inclusion of maize or oilseeds should assist in this way by increasing the energy density of the overall ration. Such work is agricultural rather than industrial, and could be implemented internally.

Utilisation of filter mud

7.07 As discussed earlier there are limitations to the use of this material as a major component of feeds. However, further analyses of samples of this material need to be carried out to determine typical mineral and trace element levels. If these are consistently as high as those previously reported, the possibility of using filter mud at low levels as a source of minerals and trace elements, even in poultry and pig feeds, needs to be investigated.

Proposals would include:

a) collection and preparation of a number of samples of filter mud from each sugar factory at selected intervals throughout a season. The samples would need to be dried, ground, and analysed for the range of constituents listed in End Table 1 (excluding amino-acids) with the addition of selenium.
6 man-months internal preparation and analytical work (assumes necessary analytical equipment available).

b) Measurement of the availability of selected elements to livestock (eg broiler chicks) in the first instance. 12 man-months (internal).

Recovery of protein from sugarcane juice

7.08 The possibility of recovering protein from cane juice appears to be more promising than attempting to extract protein from cane tops, because the cost of extraction and any heating required can be charged against the cost of sugar production. Apart from heating, a number of other methods are now available for precipitation of protein from liquids. These include flocculation with lignosulphonate, and the use of ion exchange resins. At the current stage of development however they are likely to be more expensive than the use of heat.

Proposals would include:

a) investigations on speed of heating cane juice, interactions of time and temperature of heating, in relation to effect of processing on digestibility of product;

b) investigation of the effect of use of eg lignosulphonates as alternative to heating, or in relation to required processing temperature;

c) supply continuous centrifuge (cost up to Rs994 250 ($97 000));

d) investigate potential for use of ion exchange methods for separation.

24 man-months (internal) would be required in the first phase of this work.

Livestock production

7.09 An experienced practical livestock production expert would be engaged for two years. His principal responsibility would be to ensure that livestock production units possess knowledge of techniques and of experimental results, and are suitably equipped and manned to carry out the investigations allocated to them. Accordingly he would spend most of his time with the producers rather than on Government or U of M installation. He would also supervise the investigations mentioned above, and be responsible for their extension to the commercial sector. His cost is estimated at Rs1.54 M (US$150 000).

Project costs

7.10 Costs of the project proposals are estimated as follows:

		Capital		
		Foreign exchange component	Local costs	Total
			Rs'000	
Sugarcane tops				
Experimental silos		1	2	3
Larger silos (to be provided on cooperating estates)				
Additives per year		20	5	25
Machinery for collecting cane tops (to be provided by cooperating estates)				
Manpower requirements		192	219	411
		213	226	439
	$'000	21.0	22.0	43.0
Bagasse and sugarcane tops				
Silos (to be provided by cooperators)				
Running costs 2 years		30	10	40
Thermo-ammoniation plant		79	39	118
Running costs 2 years		45	14	59
Manpower requirements		64	292	356
		218	335	573
	$'000	21.3	34.6	55.9
Filter mud				
Manpower requirements			219	219
	$'000		21.4	21.4
Recovery of protein from sugarcane juice				
Continuous centrifuge		888	106	994
Manpower requirements			292	292
		888	398	1 286
	$'000	86.6	38.8	125.4
Livestock production				
Manpower requirements		1 540	-	1 540
	$'000	150.0		150.0
Totals	Rs'000	2 859	1 198	4 057
	$'000	278.7	116.8	395.5

END TABLES

Mauritius: composition of dried filter mud (air-dry basis) End Table 1

Constituent	Concentration a/ %	Amino-acid	Concentration b/ %
Dry matter	92.9	Aspartic acid	1.15
Crude fibre	9.2	Threonine	0.66
Crude protein	12.4	Serine	0.61
Ether extract	8.6	Glutamic acid	1.55
Ash	13.1	Glycine	0.81
NFE (by difference)	49.6	Alanine	0.68
(Inc sugars	21.5)	Valine	0.61
Silicon (Si)	3.5	Methionine	0.27
Calcium (Ca)	2.4	Cystine	0.04
Phosphorus (P)	0.98	Isoleucine	0.49
Magnesium (Mg)	0.50	Leucine	1.12
Iron (Fe)	1.28	Tyrosine	0.56
Potassium (K)	0.40	Phenylalanine	0.62
		Ornithine	0.19
	ppm	Lysine	0.39
Copper (Cu)	350	Histidine	0.30
Zinc (Zn)	251	Arginine	0.55
Manganese (Mn)	854		
Cobalt (Co)	1.5		

a/ Mean of results from two laboratories.
b/ Result from one laboratory only.

Source: UNDP/FAO (1970) Milk and Meat Project, Mauritius. Tech Report No 1 FAO: Rome.

Mauritius: compound feed production, 1980 (t)

End Table 2

Mill	Total feed production	Principal customers	Production of individual feeds					
			Poultry	Pigs	Cattle	Horses	Prawns	Other
Government feed mill Richelieu	4 300	Govt farms (2/3) Sugar estates (1/6) Small cowkeepers (1/6)	1 100	280	1 535	17	-	1 368
Livestock Feeds Limited	18 716	Own use Private producers	17 500	425	323	115	39	314
Mauritius Farms Limited	6 600	Mainly own use	6 600	-	-	-	-	-
Totals	29 616		25 200	705	132	39	1 682	

Composition of other feed raw materials

End Table 3

Raw material	Nutrient content, % air dry sample						(ME, MJ/kg)	
	DM	Crude protein	Crude fibre	Ether extract	Ash	NFE	Ruminants	Poultry
Dried poultry manure	92.2	26.6	8.2	1.4	16.7	39.3	7.3	-
Maize	86.0	9.0	3.0	4.0	1.2	68.8	12.1	14.2
Maize stover	85.0	5.0	32.7	1.5	4.8	41.0	6.2	-
Maize and cob meal	86.0	8.1	6.7	2.2	1.4	67.6	N/A	-
Groundnut cake (decorticated)	90.0	45.4	6.5	6.0	5.7	26.4	11.6	11.5
Soyabean meal (45% P)	90.0	45.3	5.2	1.5	5.6	32.4	11.1	9.4
Soyabeans, whole	95.0	38.0	5.0	20.0	4.9	27.1	13.4	13.1
Copra cake	90.0	21.2	11.4	7.3	5.9	44.2	11.7	6.9
Leucaena (fresh twigs)	88.0	24.4	9.2	2.8	3.1	48.5	N/A	-
Napier grass (6 weeks cut) (*Pennisetum purpureum*)	88.0	8.8	27.8	1.8	13.5	36.1	N/A	-
Napier grass (mature)	88.0	6.7	31.0	1.2	13.0	36.1	N/A	-
Legume, *Stylosanthes gracilis*	88.0	15.9	23.6	1.8	7.3	39.4	N/A	-

Compiled from various sources.

Least cost formulations

End Table 4

	Formulation No 1 ME 9.75 to 10.25 No RM restrictions Beef 1 Optimal Solution Cost: Rs635	Formulation No 2 ME 9.25 to 9.75 No RM restrictions Beef 2 Optimal Solution Cost: Rs603	Formulation No 3 ME 8.75 to 9.25 No RM restrictions Beef 3 Optimal Solution Cost: Rs572	Formulation No 4 ME 9.75 to 10.25 Molasses 15% Max Beef 1 Optimal Solution Cost: Rs777	Formulation No 5 ME 9.25 to 9.75 Molasses 15% Max Beef 2 Optimal Solution Cost: Rs694	Formulation No 6 ME 8.75 to 9.25 Molasses 15% Max Beef 3 Optimal Solution Cost: Rs626
Molasses	61.2	54.3	47.5	15.0	15.0	15.0
Bagasse	35.9	42.7	49.5	-	-	14.3
Urea	2.9	3.0	3.0	-	-	-
Leucaena	-	-	-	41.9	34.8	30.2
Treated bagasse	-	-	-	42.0	33.4	-
Palm oil	-	-	-	1.1	-	-
Cane tops	-	-	-	-	16.8	40.5
	100	100	100	100	100	100
<u>Analysis</u>						
Protein	10.5	10.5	10.5	11.5	10.5	10.5
ME	9.75	9.25	8.75	9.75	9.25	8.75

End Table 4 cont

	Formulation No 7 ME 9.75 to 10.25 Molasses: 15% Max Leucaena: 20% Max Maize: 10% Min Beef 1 Optimal solution Cost: Rs918	Formulation No 8 ME 9.25 to 9.75 Molasses: 15% Max Leucaena: 20% Max Maize: 10% Min Beef 2 Optimal solution Cost: Rs836	Formulation No 9 ME 8.75 to 9.25 Molasses: 15% Max Leucaena: 20% Max Maize: 10% Min Beef 3 Optimal solution Cost: Rs788	Formulation No 10 ME 9.75 to 10.25 Molasses 15% Max Leucaena: 20% Max Maize: 10% Min Cot.seed cake: 5% Min Beef 1 Optimal solution Cost: Rs1 011	Formulation No 11 ME 9.25 to 9.75 Restrictions as in No 10 Beef 2 Optimal solution Cost: Rs942	Formulation No 12 ME 8.75 to 9.25 Restrictions as in No 10 Beef 3 Optimal solution Cost: Rs893
Molasses	15.0	15.0	15.0	15.0	15.0	15.0
Cane tops	53.2	49.7	25.9	31.5	35.5	9.8
Maize	10.0	10.0	10.0	10.0	10.0	10.0
Bagasse	-	4.9	28.3	-	15.3	39.8
Urea	0.4	0.4	0.8	-	-	0.4
Leucaena	20.0	20.0	20.0	20.0	19.2	20.0
Palm oil	1.4	-	-	0.4	-	-
Treated bagasse	-	-	-	18.1	-	-
Cotton seed cake	-	-	-	5.0	5.0	5.0
	100	100	100	100	100	100
<u>Analysis</u>						
Protein	10.5	10.5	10.5	10.5	10.5	10.5
ME	9.75	9.25	8.75	9.75	9.25	8.75

APPENDIX 5

Ranging, rejection and sensitivity data for formulation 9 in End Table 3 (Costs in rupees)

End Table 5

Ranging		Rejection		Sensitivity	
<u>Molasses</u>		<u>Treated cane tops</u>		(Maximum)	<u>Molasses</u>
Cost:	751	Cost:	983	Unit cost:	2.33
Low:	-inf	Includes:	688	High %:	22.5
%:	Maximum	%:	13.3	Save:	17
High:	934			Low %:	3.3
%:	3.3			Cost:	27
<u>Cane tops</u>		<u>Treated bagasse</u>		(Minimum)	<u>Maize</u>
Cost:	500	Cost:	542	Unit cost:	13.48
Low:	470	Includes:	471	Low %	0.1
%:	72.8	%:	23.6	Save:	152
High:	562			High %:	16.6
%:	13.2			Cost:	103
<u>Bagasse</u>		<u>Cottonseed cake</u>		(Maximum)	<u>Leucaena</u>
Cost:	252	Cost:	3 415	Unit cost:	0.72
Low:	90	Cst:	1 306	High:	30.8
%:	51.8	%:	8.1	Save:	8
High:	302			Low:	0.3
%:	0			Cost:	14
<u>Maize</u>		<u>Soyabean meal</u>		(Minimum)	<u>Protein</u>
Cost:	2 674	Cost:	4 600	Unit cost:	11.57
Cst:	1 126	Cst:	1 481	Low:	8.0
%:	16.6	%:	7.0	Save:	29
Cst:	+inf.			High:	11.5
%:	Minimum			Cost:	12
<u>Urea</u>		<u>Palm Oil</u>		(Minimum)	<u>ME</u>
Cost:	2 970	Cost:	5 125	Unit cost:	95.06
Cst:	1 542.913	Cst:	3 086	Low:	8.2
%:	1.8	%:	1.8	Save:	52
Cst:	3 887			High:	9.25
%:	0			Cost:	48
<u>Leucaena</u>		<u>Dried poultry manure</u>		(Maximum)	<u>Volume</u>
Cost:	909	Cost:	800	Unit cost:	2.71
Cst:	-inf.	Cst:	731	High:	109.9
%:	Maximum	%:	11.4	Save:	27
Cst:	981			Low:	100
%:	0.3				

Notes to End Table 5

a/ Ranging This indicates the downward and upward changes in price which can take place without affecting the formulation; in this example, if the cane tops price were 470 Rs/t, the inclusion rate would increase to 72.8%; if the price were increased to 562 Rs/t, the inclusion rate would then fall to 13.2%.

b/ Rejection This indicates the price at which a raw material would be included (in effect the "shadow" price). For example, treated bagasse has been rejected at 542 Rs/t; but if it could be made available at 471 Rs/t, 23.6% would be included.

c/ Sensitivity This indicates the cost of one unit of each component, and shows the effect on costs if the specification of the formulation is changed. For example, 1 unit of ME costs Rs95.06 (NB 1 unit CP = Rs11.57). Reducing the minimum ME specification from 8.75 MJ/kg to 8.2 MJ/kg would save 52 Rs/t feed DM. (This would have to be offset against a possible lower growth rate).

Raw material assumptions and specifications for feed formulation — End Table 6

Raw material	Code	ME Content DM	Crude protein % DM	Price Rs/t	DM Basis Rs/t
Molasses	Md	12.7	4.1	600	751
Cane tops	CT	7.5 (say)	5.0	150	500
Treated cane tops a/	TCT	9.5 (say)	4.8	295	983
Bagasse	Bag	5.5 (say)	-	126	252
Treated bagasse a/	T Bag	7.8 (say)	-	271	542
Maize grain	Maize	13.5	9.8	2 300	2 674
Cottonseed cake	CSC	11.4	42.6	3 074	3 415
Soyabean meal	SBM	12.3	50.3	4 141	4 600
Urea	Urea	Nil	280.0	2 970	2 970
Leucaena	Leuc	10.0 (say)	26.0	200	909
Palm oil	P.oil	35.0	-	5 125	5 125
Dried poultry manure	DPM	7.3	26.6	266	800

a/ Caustic soda followed by ensiling.

APPENDIX 6A

BY-PRODUCTS: FERMENTATION AND DISTILLATION PRODUCTS

ETHANOL AS A FUEL

CONTENTS

CONTENTS (cont)

SUMMARY

1. Ethanol can be used as a motor fuel either on its own or blended with gasoline. Use on its own is not considered for the following reasons. Firstly expensive modifications would be needed to existing petrol-driven vehicles; a compression ratio of 12:1 would be required for an ethanol-only fuel to work satisfactorily. Secondly, present molasses production of 191 000 t/y 1/ would produce 48 M ℓ of ethanol, which falls short of forecasts of gasoline demand (given parity between ethanol and gasoline consumptions). Sales are estimated at 48 M ℓ gasoline in 1983. This would rise slightly faster than GNP, around 2-3%/y, reaching 55-60 M ℓ/y by 1990.

2. The petroleum companies in Mauritius are satisfied that a blend of 80% gasoline/20% ethanol would be a satisfactory motor fuel, with relatively small conversion costs of existing terminal and forecourt installations. These are estimated at Rs2.96 M ($0.29 M), with extra annual operating costs of Rs255 000/y ($24 800). Further operating tests are to be carried out in January 1982 in order to confirm that vapour-lock problems are not serious.

3. The technical aspects of producing 12 M ℓ/y (20% of 60 M ℓ) are described. Recommendations are made in favour of

- Pasteurisation and clarification of molasses
- Rapid batch fermentation with yeast re-cycling
- The use of benzene as an entrainer
- A distillation section in which the analysing/rectifying column and the dehydrating column operate at different pressures.
- The analysing/rectifying column to be fitted with sieve trays, and the other columns with valve trays.

4. Vinasse evaporation and/or incineration are not considered due to high capital costs. A detailed study of the production and use of methane from vinasse should have been made by the time of the feasibility study of the distillery. A pilot plant for anaerobic digestion of methane is recommended at Beau Plan, at a cost of Rs7 M ($0.68 M).

1/ Appendix 1, para 3.02.

5. Three options are examined:

a) a 107 000 ℓ/d distillery operating during crop, with a maximum output in a 134 d crop of 14.3 M ℓ/y;

b) a 50 000 ℓ/d distillery operating 300 d/y, producing a maximum of 15 M ℓ/y;

c) a 30 000 ℓ/d extension of the existing Beau Plan distillery, producing in total 50 000 ℓ/d, or 15 M ℓ/y.

6. A further option, the addition of 50 000 ℓ/d to Beau Plan was not considered, not being materially different in costs and benefits to Option B.

7. Option A is described in detail, and Options B and C are outlined. Summary costs are as follows:

		Capital		Operating (2nd and subsequent years)	
	para	Rs M	[illegible]	Rs M	$ M
Option A	(6.30)	122	[illegible]	46	4.5
B	(7.06)	92	9.0	57	5.6
C	(8.04)	62	6.1	57	5.6
Option A with vinasse digester	(6.31)	150	14.6	45	4.4

8. Unit operating costs, including depreciation and interest, are:

	Rs/ℓ	US¢/ℓ
Option A	4.39	42
Option B	4.65	45
Option C	4.67	45
Option A with vinasse digester	4.59	45

9. Only Option A has a positive rate of return at July 1981 prices (1.1%). Indeed in this field rates of return depend largely on the assumptions that are made about the movements of prices of gasoline and molasses in real terms (ie in relation to the prices of other traded goods). On

the assumption that prices of both gasoline and molasses will rise 3%/y in real terms from mid 1981 onwards, rates of return are

Option A	7.8%
B	2.9%
C	0

10. These are unattractive by any standards; however as time goes on, increases in gasoline and molasses prices will work in favour of the distillery. For example, if Option A were built in 1990, its rate of return would rise to 12.5%. The results of other assumptions are shown in Section 9.

11. Energy ratios (ie the ratios of the energy produced to the energy consumed - valuing bagasse at zero) of the distillery are as follows:

Vinasse disposal in fields	1.79
Vinasse evaporation	1.05
Vinasse incineration	2.15
Anaerobic digestion of vinasse	3.76

12. The IRR on the anaerobic digester would be only 3.5%, since the methane is replacing low-cost steam. (It would be much higher with Option B).

13. the IRR of Option B, using bagasse pellets instead of fuel oil in the out-of-crop, is 7.6%, still below Option A. This uses an opportunity cost of bagasse pellets based on coal, but it takes no account of the electricity foregone by not burning pellets in a power station.

14. A pilot anaerobic digestion plant is recommended at the Beau Plan distillery at a capital cost of Rs7 M ($680 000).

15. A Central Energy Planning Committee should be set up with powers to develop and enforce a national energy policy. It would be responsible to the Authority at Ministerial level which is recommended to develop the sugarcane by-products industry.

1. INTRODUCTION

Ethanol as a petroleum product extender

1.01 Historical background Ethanol has been known to be a possible fuel for internal combustion engines since their development at the end of the nineteenth century. The availability of low cost gasoline meant that it rapidly superseded ethanol as the primary fuel for motor car engines. During the Second World War interest in ethanol fuels was revived when oil shortages and petrol rationing became widespread. Many countries experimented with ethanol/gasoline blends suitable for motor cars and aircraft engines. The development of these blended fuels virtually ceased after the Second World War when high octane petroleum products became available at low prices.

1.02 Since the dramatic increase in the price of oil products in the early 1970's and the concern over adequacy and reliability of future supplies there has been renewed interest in the production of ethanol from biomass sources as a supplement to petroleum fuels or as a fuel in its own right.

1.03 Ethanol as a gasoline substitute Ethanol may be used as a fuel in a hydrated form 1/ with the composition 95% ethanol and 5% water. This fuel requires considerable modifications to engine design in order to produce a high compression ratio (12 to 1) that will maximise performance. In addition, entire replacement of the imports of gasoline to Mauritius with ethanol would require the production of 60 M ℓ per year of ethanol. Even if all available molasses were converted to ethanol only about 70% of the total requirement of ethanol would be produced. In practice the use of "straight" ethanol as a fuel in Mauritius is unlikely.

1.04 Anhydrous ethanol 2/ may be blended with gasoline up to a 20% ethanol/80% gasoline ratio and used without any modifications to normal gasoline engines, except for a

---

1/ The constant boiling azeotrope of ethanol has the composition 95.6% w/w ethanol, 4.4% w/w water. Hydrated ethanol is the term given to ethanol distilled at a composition close to the constant boiling composition, ie in practical terms contains approximately 95% ethanol 5% w/w water.

2/ Anhydrous ethanol is ethanol from which most of the water has been removed. The typical composition of "anhydrous" ethanol is 99.7% w/w ethanol and 0.3% w/w water.

certain degree of re-tuning. The ethanol/gasoline fuel improves combustion efficiency and no loss of performance is experienced although the calorific value of this fuel is slightly lower than that of pure gasoline. Addition of ethanol also improves the octane rating which avoids the requirement for antiknock additives such as tetraethyl lead.

	Calorific value kcal/kg
Gasoline, 87 RON	10 270
Ethanol, 100%	6 450
20% Ethanol/80% Gasoline blend	9 510

Source: Technical Data on fuel.

	Research Octane No (RON)
Gasoline, premium grade	95
20% ethanol/80% premium gasoline	100
Gasoline, regular grade	87
20% ethanol/80% regular gasoline	97

Source: Shell Company of the Islands Limited, Mauritius.

Experience with cars using ethanol/gasoline fuel in Brazil, Zimbabwe and the USA has shown that there is no significant loss of fuel economy. Given these facts it is considered that the possible use of ethanol, locally produced from molasses and for blending with imported gasoline, should be further investigated.

1.05 Ethanol as a substitute for diesel Experiments have been undertaken, primarily in Brazil, to establish the feasibility of blending ethanol with diesel fuel. The upper limit of ethanol concentration is considered to be between 5% and 10%. Higher concentrations of ethanol inhibit the ability of the fuel to autoignite and combust uniformly. Economically, there are doubts as to whether ethanol/diesel blends will be possible because the required ethanol consumption is 1.6 to 1.8 times greater than that of diesel. Technically the oil companies have reservations because even small quantities of ethanol dramatically lower the flash point of the fuel, posing handling and storage dangers

Ethanol in diesel fuel %	Flash point °C
0	70.0
2	14.4
5	10.8
7	10.1

1.06 In these circumstances ethanol/diesel blends cannot be considered as a viable utilisation of ethanol in Mauritius.

1.07 Ethanol as a substitute for kerosene Kerosene is used extensively in Mauritius as a fuel for domestic cooking. Ethanol has a lower calorific value than kerosene which increases the fuel consumption by one third.

	Calorific value kcal/kg
Ethanol (100%)	6 450
Kerosene	10 390

Unless a suitable price differential is created, ethanol is unlikely to replace kerosene as a domestic fuel.

Potential demand for ethanol if it was used as a partial substitute for gasoline

1.08 The only market for ethanol would be as a substitute for gasoline at a maximum substitution rate of 20%. The potential market size is a function of gasoline consumption.

1.09 Gasoline consumption Figures for the consumption of gasoline in Mauritius show that it more than doubled from 1971 to reach a peak of 67.2 M ℓ (14.8 M gal) in 1978 - an annual average growth rate of over 11%. In 1979, however, consumption fell back slightly and then declined by a further 18% in 1980. This drop reflects the general stagnation in economic growth over this period, and the consequent reduction in consumer spending power. In particular, the rapid rise in gasoline prices had a major impact on consumption. Detailed consumption figures are in End Table 1.

1.10 Between January 1979 and July 1981, the retail price of premium grade gasoline (95 RON) almost trebled from Rs2.42 to 6.60/ℓ ($0.40 to 0.76/ℓ), whilst the cif price more than trebled. The consumer price index rose by some 75% over this same period. Details of price movements are at End Table 2.

In July 1981 the price structures for premium and regular grades of gasoline were as follows:

	Premium		Regular	
	Rs/ℓ	Rs/g	Rs/ℓ	Rs/g
Cif price	2.80	12.72	2.73	12.42
Duty	3.13	14.25	3.13	14.24
Handing and distribution costs	0.67	3.03	0.63	2.84
Retail price	6.60	30.00	6.49	29.50
$	0.76	3.46	0.75	3.40

Retail prices will have risen with the 1981 devaluation to expected levels of Rs7.8/ℓ (premium) and Rs7.67/ℓ. Cif prices will have risen to Rs3.31/ℓ and 3.22/ℓ.

1.11 Although consumption of gasoline has been falling, price increases have meant that total costs of gasoline imports have continued to rise; by 1980 the cif value of premium and regular grade gasoline consumed in the country was Rs115 M ($13.3 M). Costs of gasoline imports cif Port Louis for inland trade were as follows:

	Rs M	$ M
1977	52.6	8.8
1978	54.9	9.2
1979	92.4	12.6
1980	115.3	13.3

1.12 Forecasts for gasoline consumption show a continuing decline in 1981, followed by a levelling off in sales, anticipated at 47.8 M ℓ in 1983. These forecasts, which are considerably lower than others made earlier in the year, reflect the deepening of the current recession and the expected slow recovery in economic growth. Of particular importance is the expected reduction in new vehicle registrations. Vehicle registrations from 1975 to 1980 are at End Table 3. With the imposition of import quotas and the current high level of import duties (over 200%) the number of new vehicles registered will continue to fall. This in turn can be expected to cause a drop in the total number of motor vehicles registered. The trend towards smaller cars with greater fuel economy is an additional influence that is likely to reduce gasoline consumption.

1.13 The position after 1983 will depend on policy measures adopted towards motor vehicle imports (both in terms of quota applications and levels of import duty); the level of gasoline prices and, in particular, levels of taxation; and the general economic climate, especially the rate of recovery from the present recession. Assuming that high duties continue to be applied to both vehicle imports and gasoline, future growth in gasoline consumption will be modest, especially in view of the relatively slow recovery forecast for economic growth. On average a growth rate slightly higher than that for GNP can be anticipated, a level of 2-3%/y therefore being suggested. At these growth rates gasoline consumption would expand to between 55 and 60 M ℓ by 1990, these figures being used as the basis for establishing the size of ethanol plant required in Mauritius.

1.14 <u>Gasoline prices</u> Future price changes for gasoline will be similar to changes in crude oil prices. Prices for the lighter fractions might rise slightly faster and for the heavier ones more slowly, but such differences are likely to be small and have been ignored.

In 1981 there has been a general weakening of oil prices. The recession in the USA and Europe has resulted in lower than expected consumption, whilst production has been sustained in the OPEC countries, notably Saudi Arabia who indeed are proposing to increase it. This is reflected in the reduced differentials between the OPEC quoted prices and the spot market ones. The expected recovery in economic activity in the industrialised countries is, however, likely to strengthen demand for oil with a consequent upward movement in prices.

1.15 Various projections have been made of the longer term trend in oil prices. Recent consensus of opinion was that growth in demand will be sufficient to enable OPEC to continue with a policy of price increases in real terms. However, this is no longer accepted by every observer, and since the result of the analysis of the viability of the ethanol plant depends on which of several assumptions one may make about the price of petroleum - and that of molasses - the present discussion continues in Section 9, Financial and Economic Analysis of options.

2. TECHNICAL CONSIDERATIONS IF ETHANOL/GASOLINE MIXTURES ARE USED

Water tolerance

2.01 Ethanol is hygroscopic and small quantities of water present in the blended fuel can result in phase separation, which makes it unusable. The quantity of water required to induce phase separation is termed the water tolerance; it increases with temperature and with the proportion of ethanol in the blend, as the following data show:

Ethanol proportion %	Temperature °C	Water tolerance %
10	0	0.20
10	25	0.34
20	0	0.54
20	25	0.83

Blend proportions

2.02 Mauritius is currently supplied with regular (87 Research Octane Number (RON)) and premium (95 RON) refined gasolines from Aden and Bahrein. Addition of 15-20% ethanol to gasoline raises the octane number of premium to 99-100 and of regular to 96-98 (para 1.04). Regular grade is therefore most suitable for blending as the final octane number is slightly better than the present premium grade fuel. The higher octane number obtained with premium grade blends is unnecessary.

2.03 The regular grade gasoline from the Persian Gulf refineries is a much "lighter" fuel than the gasoline blended with ethanol in Brazil and Zimbabwe. A comparison of physical properties indicates that the Reid Vapour Pressure is higher and the Final Boiling Point of Mauritian gasoline is lower.

	Mauritius	Brazil and Zimbabwe
Reid Vapour Pressure (mbar)	605	336-363
Final Boiling Point (°C)	170-175	205-215

Addition of ethanol, a component with a low boiling point of 78°C raises the vapour pressure of the fuel as follows:

% Ethanol	Reid Vapour Pressure (mbar)
0	605
15	673

This effect raises the proportion of the blended petrol which evaporates at 75°C compared with gasoline itself. If the proportion which evaporates at 75°C becomes too high there is a risk of gasification of fuel before injection into the carburetter, causing vapour lock problems.

2.04 Experimental results which Shell International have obtained indicate that a 20% ethanol/80% gasoline blend does not result in vapour lock problems. A trial was undertaken by Shell in Mauritius during May 1981 in which 20 cars of different makes and sizes were run using a 20% ethanol/80% gasoline fuel. The results from questionnaires completed by the drivers of these cars have led Shell to the preliminary conclusion that a 20/80 blend poses no vehicle handling problems under Mauritian climate and driving conditions. A further, more extensive, series of trials to confirm previous conclusions, is planned by Shell to take place during the hotter weather of the early months of 1982. It is not anticipated that the final conclusions will be markedly different from those deduced at present.

2.05 This study is therefore based on the premise that a blend of 20% ethanol/80% gasoline will be recommended as technically the most suitable for Mauritius.

Ethanol specifications

2.06 Although the specification of ethanol for blending with gasoline has not yet been finalised by the oil companies or the Government of Mauritius it is expected that the specification will be similar to that currently in force in Brazil. That is:

Ethanol content	99.3% w/w minimum 99.6% w/w preferred
Specific gravity	0.7915
Acidicity, as acetic acid	3.0 mg/100 ml maximum
Non volatiles	5.0 mg/100 ml maximum
Copper	0.07 ppm maximum
Alkalinity	Nil

Addition of fusel oils

2.07 Fusel oils are higher molecular weight alcohols, including propanol, butanol and amyl alcohol, which result from various unwanted fermentation reactions. Fusel oils accumulate in the rectifying section of the first distillation column and are removed together with some ethanol. Shell have advised that it would be practical to blend the fusel oils with the ethanol and that this would have the following advantages:

a) fusel oils have a higher calorific value than ethanol, and that of the fuel would be enhanced;

b) addition of fusel oils improves the phase stability of the ethanol/gasoline blend;

c) total fuel output of the distillery is improved; and

d) fusel oils raise the boiling point of the mixture.

Denaturant

2.08 Ethanol from the distillery must be denatured to render it unsuitable for human consumption. Fusel oils, blended with the product, assist in denaturing the ethanol. Often pyridine is used for this purpose but its unpleasant smell would be objectionable to filling station staff and motorists. It is proposed that gasoline should be used for denaturing, since this will not introduce another chemical into the final ethanol/gasoline blend. 3 ℓ of gasoline per 100 ℓ of ethanol would be required. It is expected that the final requirements for denaturing would be the subject of government regulations, following careful study of the risks of abuse of ethanol blended fuel.

Ethanol handling, storage and blending

2.09 Shell have undertaken an objective and critical examination of the handling, storage, blending and distribution of ethanol/gasoline blends in Mauritius. Their study included an estimate of the capital expenditure needed to convert storage facilities and filing stations to handle these blends. Shell's report also reflects the opinions of the other oil companies in Mauritius.

2.10 The principal conclusions of Shell's report are:

a) Transport The present gasoline road tanker fleet is suitable for transporting gasoline/ethanol blends providing that non-ethanol resistant seals, gaskets and hoses etc are replaced.

b) Blending A type of preset proportional blender should be used for ensuring accurate blending of the correct quantity of ethanol to the fuel. This type of blender is already in use in Zimbabwe and South Africa. Quality control procedures for determining the ethanol and water content of the blend would have to be implemented.

c) Storage The existing storage tank facilities at the Shell/BP and Esso depots have a capacity for up to 60 days storage of ethanol, and tanks are available for the blending operation. Caltex does not have any spare tanks for the blending process.

d) Preparation of service stations The mild steel storage tanks currently in use are suitable for ethanol/gasoline blends providing care is taken to ensure against the ingress of any water. Tank manhole seals will require replacing to prevent entry of rain water, and caps on fill and dip pipes will need some modification. The tanks should be thoroughly cleaned before being filled with ethanol/gasoline fuel. Petrol pump seals and pipeline gaskets will need to be replaced where not made of ethanol resistant materials.

e) Capital exenditure at Shell/BP installations These would be as follows:

		Rs
i)	Unloading facilities added for ethanol to tank No 10	258 000
ii)	Cost of in-line blending into tank No 4	361 000
iii)	Modifications to blend outlet from tank No 4	63 000
iv)	Fire-fighting equipment	268 000
v)	Contingencies	57 000
	Total	1 007 000
		$ 98 200

f) Capital expenditure at Esso terminal The following would be required:

		Rs
i)	Ethanol loading facilities at tank No 3	235 000
ii)	Inline blending into tank No 2	360 000
iii)	Modificators to outlet of tank No 2	83 000
iv)	Firefighting equipment	268 000
v)	Contingencies	57 000
	Total	1 003 000
		$ 97 800

g) Modifications to retail outlets The necessary modifications would be as follows:

		Rs
i)	Modifications to manholes and seals	349 000
ii)	Renewal of snap-on connections on fill and dip pipes	105 000
	Total	554 000
		$ 54 000

h) Cost of cleaning storage tanks Details are as follows:

Estimated cost of cleaning 150 tanks with alcohol	Rs396 000
	$ 38 600

i) Additional operating costs Estimates of additional operating costs, including labour, maintenance, quality control and services, that will be incurred by the oil industry for receiving, blending and distributing ethanol/gasoline fuel would be Rs255 000/y ($24 800).

The total costs to the petroleum industry in Mauritius of changing to a 20% ethanol/80% gasoline blend would therefore be:

	Rs'000	$'000
Capital	2 960	288.6
Recurrent	255/y	24.8/y

The costs in this paragraph are as given to the team by Shell, adjusted to take account of the 1981 devaluation.

3. DISTILLERY CAPACITY REQUIRED FOR ETHANOL PRODUCTION

Plant capacity

3.01 The projection of gasoline demand for 1990 indicates that the total demand for both premium and regular grades is likely to be between 55 and 60 M ℓ/year (12-13 M gal). If ethanol is substituted in the ratio 20% ethanol/80% gasoline the requirement for ethanol will be between 11 and 12 M ℓ/year (2.4-2.6 M gal).

3.02 It would be advisable to consider an ethanol distillery capable of manufacturing the higher predicted quantity of 12 M ℓ/year required in 1990, and for the distillery to have some spare capacity in view of the fact that its operating life could be in excess of 20-25 years. A distillery for producing 15 M ℓ of ethanol per year has therefore been selected as the basis for further consideration.

Plant utilisation

3.03 The major considerations regarding the daily output of the distillery are:

a) whether the plant will operate continuously for seven days each week, or for only six days a week being shut down on Sundays; and

b) whether the plant will be operational for the entire year or during the crop harvesting season only.

The sugar factories in Mauritius normally operate for six days a week and do not mill on Sundays. However, there is a potable alcohol distillery on the island operating a seven day week shift system using factory steam and power. With this precedent having been set it is recommended that a fuel ethanol distillery should work a similar shift system. This will significantly reduce the quantities of below specification product that are inevitably produced when a continuous distillation plant is frequently shut down and re-started. A four column system which is necessary for production of anhydrous ethanol will take three or four hours from initial start-up to achieve the steady state operating conditions necessary to distil products of the correct specification, giving waste of about 3% of production (in addition to 14% for the day lost). It will therefore be assumed that the distillery will operate continuously for seven days a week and that steam and other services will be continuously available.

3.04 It is expected that a distillery designed to operate for the whole year will in practice be operational for 300 d/y when allowance for maintenance periods is made. The number of days during which sugar is milled in Mauritius is rising. The average length in the non-disaster years 1972-79 was 134 days. A distillery operating for 7 days each week is thus assumed to be operational for 134 days during the crop season. The precise number of operating days in crop will depend on the factory chosen, and will vary from year to year. Factors affecting the choice of in crop or year round operation are summarised in the table below:

	In crop operation	Year round operation
Days per annum operation	134	300 134 in crop 166 out of crop
Daily plant capacity	107 000 ℓ/day	50 000 ℓ/day
Molasses storage	30 days operation 2 3 000 m^3 tanks	160 days operation 6 5 000 m^3 tanks
Ethanol storage	160 days production 2 5 000 m^3 tanks	30 days 2 800 m^3 tanks
Steam supply	Ex sugar factory	134 days-ex sugar factory 166 days-from oil fired boiler

4. TECHNOLOGY INVOLVED IN ETHANOL PRODUCTION

Pretreatment of molasses

4.01 Molasses received by the distillery from the sugar factory typically contains between 42% and 50% fermentable sugars at 80-87° brix. Before fermentation the molasses must undergo a series of pretreatment steps comprising dilution, pasteurisation and clarification.

Dilution

4.02 Raw molasses has a sugar concentration which is much too high for effective fermentation by commercial strains of yeast. It is also a viscous fluid requiring considerable energy for pumping. It is therefore essential for raw molasses to be diluted to between 16 and 20% fermentable sugar concentration before being transferred to the fermenting vessels. The resulting ethanol concentration at the completion of fermentation is between 7 and 9%. The activity of the yeast is reduced the higher the ethanol concentration becomes and above 11-12% the yeast is almost completely inhibited. There is no advantage, therefore, in attempting to ferment at sugar concentrations above 20%.

4.03 Although fermentation may be more efficient if the molasses is diluted to below 16% sugar content, the lower resulting ethanol concentration will require more energy in the distillation plant to remove the increased quantity of water. For example about 20% more steam is required to distil a 6% compared with an 8% ethanol solution.

Pasteurisation

4.04 Pasteurisation of molasses is recommended in order to reduce potential infection and bacterial contamination of the yeast. This is of particular importance if the yeast is to be recycled, since a build-up of infection could require the complete replacement of the yeast by a fresh culture after three or four cycles.

4.05 A typical fermenting vessel for a fuel ethanol distillery would have a capacity of at least 80 m^3 of fermenting liquor. Serious infection in one fermenter could result in the loss of over 6 000 ℓ of alcohol. Precautions to reduce infection are therefore essential.

4.06 If the distillery is located adjacent to sugarcane fields pasteurisation is of greater importance. Many strains of wild yeast have been identified growing on the stems of sugarcane. These have also been detected in the atmosphere surrounding the fields. Pasteurisation will kill any wild yeast strains present in the raw molasses and prevent their carry over and growth in the fermenting vessels.

4.07 Pasteurisation involves heating the diluted molasses with steam and holding it at a temperature of between 85°C and 95°C for several seconds. It is not unknown for yeast cultures to be continually recycled for several years when care is taken to minimise the introduction of unwanted bacteria, including periodic cleaning of equipment and pasteurising the molasses.

Clarification

4.08 Raw molasses contains sand, other inorganic solids and calcium salts which, although they do not seriously reduce the fermentation efficiency, have adverse effects on the down-stream processing. The solids are very abrasive and cause increased erosion of the nozzles of the centrifuge which separates the yeast from the fermented wash. Furthermore, because the solids are removed with the yeast and cannot easily be separated from it, the quantity of yeast that may be recycled to the fermenters is progressively reduced. Alternatively a large build-up of inorganic solids in the fermenters would take place.

4.09 The calcium salts which are soluble at normal temperatures and neutral pH are precipitated at low pH and high temperatures. These conditions are present at the feed point of the first distillation column. Distilleries whose molasses is unclarified experience a build up of calcium deposits on the trays of the first distillation column and in the feed preheaters (if used). Yeast and other solids will also be deposited if there is no yeast filtration following fermentation. The rate of deposition of solids is difficult to predict, being dependent on the composition of the molasses, and the temperature, pH and concentration conditions within the column.

4.10 Experience with operating plants shows that without molasses clarification the distillation column may require thorough descaling every few weeks. This involves chipping off deposited calcium sulphate. With a clarified molasses feed a simple steaming out or wash with hot water every three or four weeks may be sufficient, with the interval between shut downs for major cleans being extended to several months. Savings from decreased maintenance and reduced plant down-time can be expected.

4.11 Clarification is usually effected in a section of plant integrated with the pasteurisation stage. Sulphuric acid is added to the diluted molasses to reduce the pH to 4.5. After heating to 85-98°C the pasteurised molasses is fed through a cyclone to remove sand and then centrifuged to remove precipitated calcium sulphate. The precipitated sludge is washed and decanted to reduce sugar losses. Overall sugar losses are usually in the range 1-3%.

4.12 Several companies offer complete molasses pretreatment units incorporating continuous dilution, pasteurisation and clarification equipment together with a local control panel.

4.13 A quantitative evaluation of the advantages of pasteurisation and clarification is difficult to make because of the lack of precise data to compare plant performance with and without these plant sections. The additional capital cost incurred by including pasteurisation and clarification amounts to approximately Rs4.4 M ($0.4 M).

4.14 In summary, pasteurisation and clarification of molasses are recommended for the following reasons:

a) to reduce infection when using recycled yeast;

b) to reduce infection from wild yeast strains;

c) to reduce alcohol losses;

d) to reduce erosion of centrifuge nozzles;

e) to maximise quantity of yeast able to be recycled;

f) to minimise distillation plant down time; and

g) to reduce maintenance costs.

Fermentation

4.15 There are essentially four types of fermentation processes from which to make a suitable selection for an ethanol distillery in Mauritius. These are:

a) Long storage batch This is the traditional fermentation process, using low yeast concentrations and a long fermentation time to achieve good ethanol concentrations.

b) Rapid batch with yeast recycling   Much higher yeast concentrations are employed to obtain reasonable ethanol concentrations within half the usual fermentation period. If maintained free from infection and bacteria, yeast can be centrifuged and recycled many times.

c) Continuous fermentation   This is an extension of the rapid batch system whereby sugar substrate is continuously fed into the top of the fermenter and ethanol solution pumped away from the base, the fermenter providing several hours retention time for the liquor. The ethanol solution passes to a continuous settling vessel where the yeast solids are separated by gravity and returned to the fermenting vessel.

d) Continuous fermentation integrated with vacuum distillation   In this process ethanol solution is pumped from the base of the fermenter to a vacuum flash vessel. Ethanol and water vapour (containing 30% w/w ethanol) are drawn through a rectifying column by a compressor where ethanol is distilled to 96%.

4.16 The important features of each system are summarised below. Precise details may vary depending upon particular design characteristics used by different companies.

Batch fermentation

	Long storage batch	Rapid batch with yeast recycle
Fermentation time	24-36 hrs	12-16 hrs
Yeast concentration	1.5-10 g/ℓ	15 g/ℓ
Ethanol concentration	up to 12% normally 10%	8%
Capital cost factor	1.8	1.0
Operating cost factor	0.96	1.0
Control required	Effective control easily maintained with local temperature and level indicators with manual operation of recirculation pumps and cooling water valves	
Maintenance	Low maintenance costs limited mainly to servicing of yeast centrifuge	

Continuous fermentation

	Continuous fermentation with conventional distillation	Continuous fermentation integrated with vacuum distillation
Fermentation time	12 hr	several hours
Yeast concentration	10-20 g/ℓ	over 20 g/ℓ
Ethanol concentration	up to 12% v/v	removed continuously then flashed to 35% v/v ethanol
Operating cost factor	1.0	0.85
Yeast recycle	Employed by both systems. Settling characteristics of yeast utilised to separate it from fermented wash without use of centrifuges.	
Control required	Accurate control of feed flowrates and product removal rates	
Maintenance	Low	Required for distillation plant compressors.
Utilities required	Electricity, steam	Electricity only

4.17 Carbon dioxide recovery Approximately 35 t/day of carbon dioxide would be produced by the fermentation process. It is not expected that this will be compressed and bottled because of the high capital cost of equipment for this purpose in relation to its likely market value. The cost of installing a typical compressing and bottling plant for this capacity would be in the region of Rs8 M (US$900 000).

4.18 Assessment of fermenting systems At present it is not recommended that a continuous fermentation plant be incorporated into an ethanol distillery in Mauritius. Both types of continuous process, although well demonstrated at the pilot plant stage, have yet to be proven on a full scale distillery. It is not advisable that a major installation in Mauritius should experience the intial operational difficulties that inevitably occur with novel processes.

4.19 An efficient batch fermenting system is suggested as the best alternative for the following reasons:

a) well-proven technology;

b) considerable expertise in Mauritius in the operation of this type of process;

c) simple efficient operation with a minimum of controls; and

d) reasonably low maintenance costs.

Improvements to a basic fermenting plant to ensure optimum yields should include:

a) external cooling using plate heat exchangers to maintain optimum fermenting temperatures of 30-32°C;

b) nitrogen and phosphate nutrients to be added to improve yeast growth. These are usually ammonium sulphate and ammonium phosphate or disodium ammonium phosphate;

c) nozzle type centrifuge to separate yeast from fermented wash for recycling; and

d) treatment of recycled yeast with sulphuric acid to reduce risk of infection.

Yeast separation and recycling

4.20 There are two advantages in separating the yeast from the fermented wash and, after acid treatment and addition of phosphate and nitrogen nutrients, recycling the yeast to the fermenters. First, the alcohol yield is increased because the fermentable sugars are converted directly to ethanol instead of being used to grow yeast cells. Secondly, a high yeast concentration can be built up in the fermenters in a shorter time, thus reducing the overall fermentation period.

4.21 Either a filter press or a centrifuge may be employed for removing the yeast solids from the fermented wash. Centrifuges may be purchased with a timing device to control the operating sequence of the machine, which enables the operation to be supervised by fewer operators than would be needed for filter presses.

Yeast propagation

4.22 It is recommended that brewers yeast, a culture of Saccnaromices cerevisiae, should be used for fermentation. When yeast is recycled it is not considered essential to keep a laboratory culture of the yeast and grow the culture on a yeast propagation plant. It is highly improbable that yeast infection or inhibition will affect more than one fermenter simultaneously, so there will always be good quality yeast available for recycling from unaffected fermenters.

4.23 It is proposed that one fermenter be fitted with the facility for sparging air into fermenting liquor. A freshly purchased batch of yeast at a concentration of 10 g/ℓ in the fermenter can then rapidly be grown under aerobic fermentation conditions to 15-20 g/ℓ and transferred to other fermenting vessels. At start-up, or when it is decided to renew the yeast culture, a batch of 800 kg of yeast would be required.

Distillation

4.24 Ethanol for blending with gasoline as motor fuel should contain a minimal quanitity of water to prevent phase separation. In practice distillation systems can be designed to reduce the water content of ethanol to less than 0.3% w/w.

4.25 Ethanol containing less than 4.4% w/w water cannot be distilled in one stage because ethanol and water form a constant boiling azeotrope at a composition of 95.6% w/w ethanol, 4.4% w/w water. To produce ethanol with a purity above its azeotropic composition requires a secondary distillation in the presence of an entraining agent to remove the remaining water.

4.26 The entrainer forms a ternary azeotrope of entrainer-ethanol-water that distils over, which on condensing will decant into two layers. The upper layer contains mainly entrainer and ethanol and is fed back to the distillation column. The lower contains water and small quantities of dissolved entrainer and ethanol. This layer is removed and often passes to another small distillation column where the dissolved entrainer and ethanol are recovered.

4.27 The two important criteria in the selection of entrainer are the minimum heat requirements for the dehydration column to distil the entrainer-ethanol-water azeotrope and the partition of ethanol between the entrainer and water layers of the decanter. Ideally all the ethanol should decant into the upper layer.

4.28 Selection of entrainer Benzene is the most widely used entrainer for two reasons: it is readily available and it effects very complete dehydration - better than 99.9% w/w ethanol. Its heat requirements are moderate and the partition coefficient comparatively good, particularly when decanted at higher temperatures.

4.29 Cyclohexane has also been successfully used as an entrainer. The heat requirements for the dehydration column are slighly lower than with benzene but the partition of ethanol between the two decanter layers is not quite as favourable.

4.30 Experiments have been made using petroleum fractions as entrainers, but their disadvantage is that the ethanol removed in the water layer from the decanter is excessive. It is possible that a mixed entrainer of benzene and petroleum fraction could help to overcome this.

4.31 Trichloroethylene is a very effective entrainer. It requires a lower energy input than benzene and less ethanol dissolves in the aqueous layer. However it is not recommended because of its greater health risk and because if traces of trichloroethylene were present in motor fuel, acidic chloride compounds would form in the engines causing severe corrosion problems. Iso-propyl ether would, theoretically, appear to have suitable properties for an efficient entrainer but these have not been demonstrated in practice. It also has the disadvantage of being highly flammable.

4.32 It is recommended that benzene should be used as the most appropriate entrainer. It is readily available as "industrial grade benzene" and performs effective dehydration without an excessive energy input.

4.33 Distillation processes There are many variations of the basic distillation process, most of which have been developed to reduce the energy requirements of achieving a product composition of at least 99.7% w/w ethanol. They can broadly be grouped into five categories which are reviewed below.

4.34 Atmospheric distillation This is the traditional process which usually consists of four distillation columns.

4.35 The analysing/rectifying column Distils the dilute fermented wash (8% ethanol) to produce ethanol close to the azeotropic composition (95%). The bottom product is vinasse containing up to 7% w/w organic solids. This column is usually heated by direct steam injection to avoid fouling the reboiler tubes with solids. Sometimes the analysing and rectifying sections are constructed separately as two columns.

4.36 The heads column Removes lighter boiling components formed during fermentation, such as acetaldehyde. If not separated, these components would adversely affect the partition of components in the entrainer decanter. The light components cannot be completely separated from ethanol and about 6-7% of the ethanol is removed in the heads product. This is normally denatured and sold as industrial methylated spirit.

4.37 The dehydration column Lowers the water content of ethanol from about 5% to less than 0.3% by distillation with an entrainer. Anhydrous ethanol is removed as the bottom product. The top vapour product is the ternary azeotrope of entrainer, ethanol and water which is condensed and decanted. When benzene is the entraining agent it is advantageous to decant at higher temperatures. In this case the decanter can be fabricated as an integral part of the distillation column where it is heated by vapours rising to the top of the column. Energy for dehydration is provided by steam to a reboiler.

4.38 The entrainer recovery column Distils the entrainer from the aqueous layer of the decanter. The aqueous residue which contains some ethanol is usually recycled to the feed. This column may be heated either by live steam or indirectly with a reboiler.

4.39 The energy requirements for an atmospheric distillation train with little or no heat recovery are in the region of 4.7-4.5 kg of steam per litre of ethanol.

4.40 Atmospheric distillation with heat recovery By preheating the feed so that it enters the first distillation column at between 70°C and 77°C modest savings in steam comsumption may be achieved. Heat may be recovered from the condensing overhead vapours of the analysing column and the dehydration column, and from the hot vinasse produced by the analysing column. By incorporating a suitable series of heat exchangers to utilise this otherwise waste heat the steam consumption may be reduced to 3.5-4.0 kg/ℓ of ethanol.

4.41 Further improvements in energy requirements may be obtained only by arranging for the condensing vapours from one column to provide the energy for distillation for another. Under normal atmospheric operation there is insufficient temperature difference between the temperatures of the vapours and the temperatures of the columns to be reboiled to make this possible. Two approaches to this problem are to employ vapour recompression or to operate distillation columns at two different pressures.

4.42 Distillation with vapour recompression If vapours from the top of one distillation column are compressed adiabatically, the temperature of the vapours will be raised. It is possible for example, to compress the overhead vapours from the analysing column, increasing their temperature from 85°C to 110°C. Vapours at 110°C would then have a 30°C temperature difference compared with the base temperature of the dehydration column and could be used as the energy source for this column. Other possibilities are available using this technique which reduces the steam consumption to between 2.0 and 3.0 kg/ℓ of ethanol. To be offset against this is the capital cost of and the electrical energy for the compressor(s).

4.43 Distillation under different pressures An alternative approach to obtaining vapour temperatures 20-30°C above column base temperatures is to operate the distillation columns at different pressures. This entails operating one column either under vacuum or another at greater than atmospheric pressure. Vacuum operation increases the electrical demand by necessitating the use of a vacuum pump. Also a larger diameter column is needed to handle vapour with a reduced density.

4.44 A column can be pressurised by its own vapours with only the use of a suitable pressure control loop. This method has the slight disadvantage of requiring steam at a higher pressure as the primary energy source. These improvements reduce the steam consumption to between 2.8 and 3.2 kg/ℓ of ethanol.

4.45 Vacuum distillation As pressure is reduced the azeotropic composition of ethanol and water changes in favour of higher ethanol concentrations. At 0.12 bar A (90 mm/kg) pressure the azeotrope contains 98.1% w/w ethanol. Higher purity ethanol could be obtained by distilling at even lower pressures, but the increased size and cost of vacuum compressors and distillation columns negate this advantage. In practice a conventional benzene column would follow using the 98.1% ethanol feed.

4.46 One company has integrated continuous atmospheric fermentation with vacuum distillation to achieve significant energy savings across the combined fermentation and distillation sections of a pilot plant. The energy is supplied as electrical power to compressors rather than as steam.

4.47 Recommendations As discussed under fermentation it is believed that continuous fermentation integrated with distillation under vacuum is not the most advisable technology to introduce to Mauritius at present. Although savings in operating costs have been demonstrated on small-scale plants, the fact that a full scale plant has not been operated and the likelihood of increased maintenance because of the use of large compressors weigh against this.

4.48 The system which offers low capital cost, ease of operation and maintenance and low energy consumption is one in which differential operating pressures for the analysing/rectifying and dehydration columns are employed. It is recommended that a distillation section design of this type should be considered. A plant in which one column operates above atmospheric pressure is preferred because this avoids the use of vacuum pumps.

Vinasse disposal

4.49 Composition and flow rate The composition of vinasse (sometimes called spent wash or stillage) from a molasses distillery depends upon many factors including where the cane is grown. A typical composition would be as follows:

BOD	mg/ℓ	20 000-30 000
COD	mg/ℓ	15 000-35 000
Organics	%	6.0-6.5
Potassium as K_2O	%	0.78
Phosphorus as P_2O_5	%	0.02
Magnesium as MgO	%	0.01
Calcium as CaO	%	0.36
Sulphates	%	0.84
pH		3.5-4.5

The flow rate of vinasse from a 107 000 ℓ/day distillery amounts to 1 500 m^3/day.

4.50 Methods of disposal There are four methods of disposal or utilisation of the vinasse effluent which require examination in the Mauritian context. These are:

a) direct disposal on land;

b) evaporation to 60% solids for use as animal feed or fertiliser;

c) evaporation and incineration; and

d) anaerobic digestion.

4.51 Direct disposal on land Vinasse can be disposed of directly onto the land on which sugarcane is grown, enabling organic matter, nitrogen, potassium, calcium, magnesium, phosphate and other minerals to be returned to the soil. This reduces the requirements for purchases of fertilisers. The daily quantities of these materials in the effluent from a 107 000 ℓ/d distillery are typically:

	t
Organics	90-96
Nitrogen	1.7
Potassium as K_2O	11.9
Calcium as Cao	5.4
Magnesium as MgO	0.15
Phosphorus as P_2O_5	0.24

The application rates used for direct irrigation of fields with vinasse effluent in Brazil vary from 75-650 m^3/ha. The composition of the soil and its deficiency in the various chemical components of vinasse determine the most suitable application rate. In particular, care must be taken to prevent excess soil acidity bearing in mind the low pH of vinasse, and partial neutralisation of with lime may be necessary to minimise corrosion. Further, the nitrogen content of vinasse can inhibit ripening of sugarcane in hot weather by encouraging vegetative growth 1/.

4.52 In many parts of Mauritius the disposal of the vinasse on the land is made particularly convenient because of well developed irrigation schemes. Indeed the distilleries at Medine and St Antoine already return their vinasse to the irrigation water being delivered to neighbouring fields. If an ethanol distillery were to be sited in an area with irrigation under command the marginal cost of adding the cooled vinasse to the irrigation water would be minimal; if not, the vinasse would have to be pumped to a suitable location at some cost in cash and in energy. If an average application rate of 50-150 m^3 of vinasse/ha/y were assumed, then a land area of 2 250-6 750 ha could be treated. Detailed studies and trials would be necessary to confirm the feasibility of this method of disposal; these could be carried out on various sites before any decision is likely to be needed about the ethanol distillery.

4.53 Evaporation The vinasse can be concentrated to 60% solids content by evaporation to reduce its bulk and make transport easier. The concentrate may be utilised either as an animal feed supplement or directly as a fertiliser on the land. Evaporation beyond 60% solids is difficult because of increased scaling of the evaporator as the concentration rises.

1/ MSIRI.

4.54 A four stage falling film evaporator would normally be specified for concentrating 1 500 m^3/day of vinasse. The capital and operating costs of evaporation are high when compared with those of the distillery itself and the limited usefulness of the concentrated syrup. The steam required for evaporation would increase the total steam requirement of the distillery by 40%. The estimated relevant cost and utilities data are:

Installed cost of evaporator plant	Rs 44 M ($4.7 M)
Steam consumption	320 t/d
Cooling water consumption	25 000 m^3/d
Electrical power	5 100 kWh/d

4.55 <u>Evaporation and incineration</u> The evaporated vinasse may be used as fuel for a boiler to generate steam. The overall energy balance of the distillery is improved because the combined evaporation/incineration system is a net producer of steam. Vinasse fired boilers are now operational in many countries including Australia and Thailand. Data are:

Installed cost of evaporator/boiler plant	Rs77.5 M ($8.2 M)
Net steam generation	90 t/d at 5 bar A or 0.84 kg/ℓ of ethanol
Cooling water consumption	25 000 m^3/d
Electrical power absorbed	9 200 kWh/d
Fuel oil for start-up	640 ℓ.

4.56 <u>Anaerobic digestion</u> The vinasse may be treated in anaerobic digesters in which suspended micro-organisms convert the organic material into biogas. This has a typical composition of 60-65% v/v methane and 35-40% v/v carbon dioxide.

4.57 The digestion process is frequently carried out in a two stage reactor plant. In the first reactor the organic substances in the vinasse are converted into volatile fatty acids. In the second phase reactor the liquor is contacted with a sludge blanket containing bacteria for the two reactions which take place. The fatty acids are broken down into acetic acid and hydrogen, and finally the hydrogen is converted into methane by the methane bacteria.

4.58 Effluent disposal is limited to a small quantity of surplus sludge that can be used as a fertiliser. The relevant data are as follows:

Installed cost of anaerobic digesters	Rs 27.4 M ($2.7 M)
Biogas generated	27 200 Nm^3/d 1/
Biogas calorific value	5 850/kcal/m^3

1/ Normal m^3, ie at 0°C and 1 bar A.

Fuel oil equivalent of biogas	17 600 ℓ/d
Steam equivalent of biogas	245 t/day at 5 bar A or 4.9 kg/ℓ of ethanol
Electrical power absorbed	1 250 kWh/d
Sodium hydroxide requirement	32 kg/d
Sludge produced	4.9 t/d.

4.59 Recommendations for vinasse disposal It is recommended that a future ethanol distillery should be located in an area where there is sufficient land under irrigation for the vinasse to be added to the irrigation water for disposal on the fields if this is required. This solution requires very little capital expenditure and contributes to reducing fertiliser costs, but extensive studies will be needed of its feasibility. It would probably be the most satisfactory solution if the distillery is to be built in the near future and if there is a shortage of capital. If, however, direct disposal is not feasible, and adequate capital is available, studies of anaerobic digestion of vinasse should be conducted; it offers the best alternative solution as it is a net energy producer (paras 10.02-03). If the distillery is delayed, as the financial analysis suggests is possible, a pilot vinasse disposal plant at Beau Plan is recommended, at an estimated cost of Rs7 M ($0.68 M).

Mechanical design of distillation plant

4.60 Plant layout Distillation plant for alcohol distilleries has traditionally utilised gravity flow of all liquid streams, to minimise the number of pumps and to keep the controls and instrumentation as simple as possible. This has necessitated large supporting structures with heavy condensers and reflux dividers being mounted about the distillation columns, often 20-30 m above ground level.

4.61 In recent years with the development of inexpensive, efficient, flameproof pumps and motors the chemical industry has developed a cheaper and more compact layout for distillation plant. By locating condenser, heat exchangers and reflux drums as low as possible, and by pumping liquids back up to the required trays of the columns, the size of the steelwork structure is greatly reduced. The columns are fitted with ladders and small platforms to provide access for maintenance. This layout produces significant cost savings as the cost of pumps and associated pipework is less than the cost of the steelwork not required.

4.62 It is proposed that this style of layout be adopted for the ethanol distillery. A structure with two levels would be required. Pumps and plate heat exchangers would be sited at ground level. Reflux drums and important controls and instruments would, where possible, be located on the first floor. The top floor would be devoted primarily to the condensers. The distillation columns would be designed to be free-standing and would be mounted adjacent to the structure.

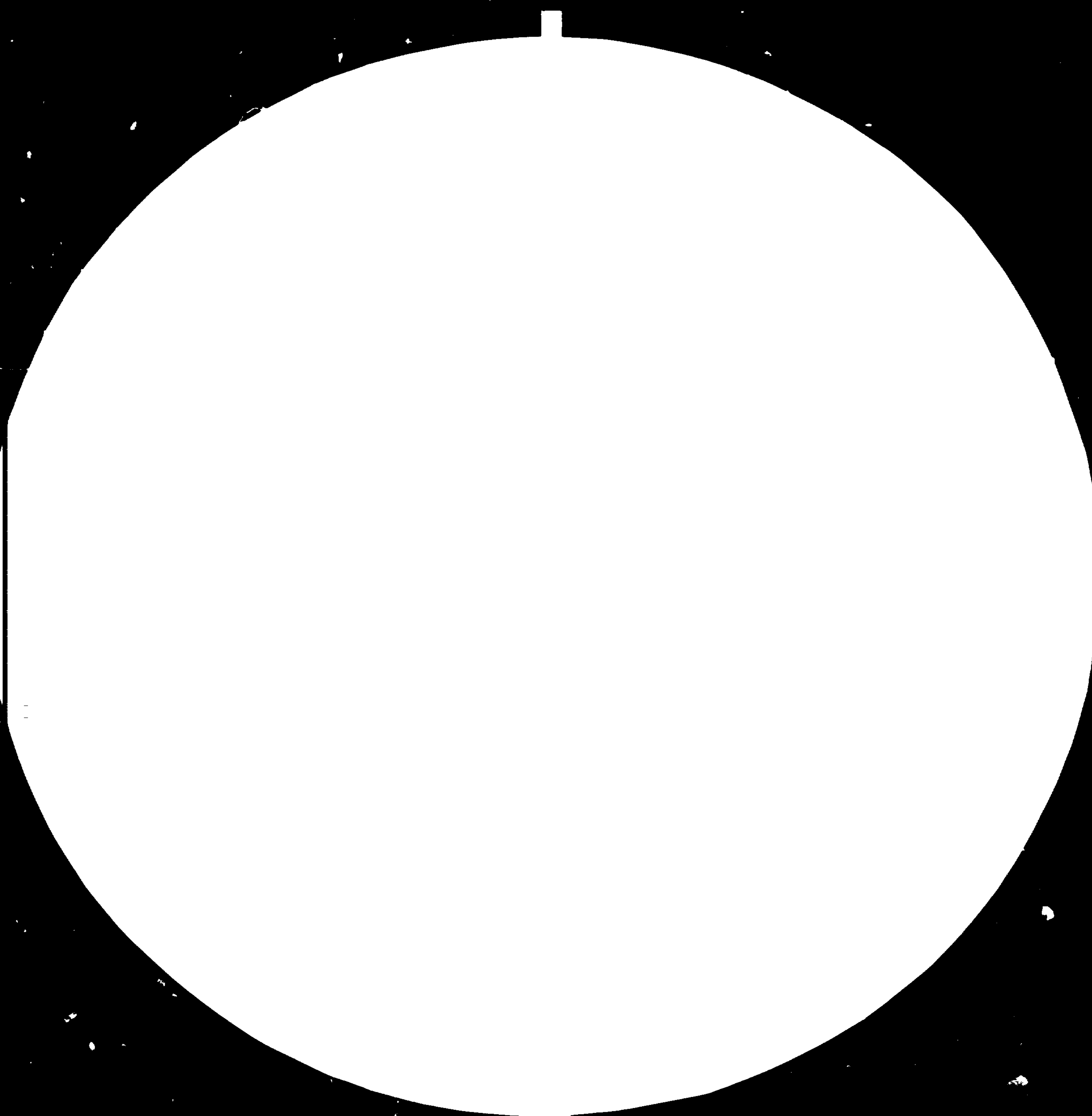
4.63 Tray design Bubble cap trays have generally been used for distillery columns. Their performance is good over a wide range of operating conditions but they are considerably more expensive to manufacture than alternatives such as sieve trays and valve trays.

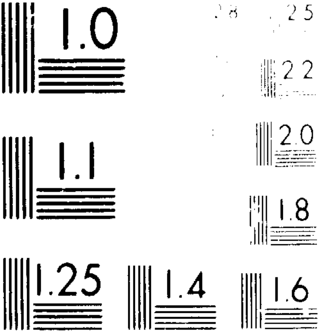
4.64 Sieve trays are much cheaper to manufacture than bubble cap trays and are particularly advantageous where a column is handling liquor with a high solids content. They are also less prone to fouling and blocking with scaling deposits. A well designed sieve tray will have nearly as good a turn down capability as a bubble cap tray.

4.65 Valve trays are the most popular type of tray now being installed in refinery, petrochemical and solvent distillation plant. Although apparently more complex than bubble cap trays the increased volume of valve trays being manufactured has led to improved and cheaper production techniques. At least one company has developed a computerised design and fabrication system enabling valve trays to be purchased at a lower cost than bubble cap trays. Valve trays can be designed to operate efficiently under a wide range of liquid and vapour loadings.

4.66 It is recommended that the analysing/rectifying column, where scaling and solids handling problems will predominate, should be fitted with sieve trays and that the other columns be supplied with valve trays for the reasons outlined above.

4.67 Distillation column design The conventional design of column for alcohol distilleries of a number of flanged sections, each containing five or six trays, is expensive to manufacture. Constuction on site is also time consuming; each section must be carefully bolted to the preceding one. An all welded construction of the type now widely fabricated for refinery and solvent recovery columns should be employed for the distillation columns, in order to reduce the fabrication cost by eliminating the flanges. Access for cleaning the larger columns would be by man holes fitted at every 15 trays. The trays themselves would be of sectional design, the middle section being easily removable, enabling a man to work his way up or down the column. On the smaller columns a handhole would be provided for each tray to facilitate cleaning.

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4.68 Construction materials The general philosophy as far as construction materials are concerned is to use stainless steel if low pH presents potential corrosion problems and where hygiene is essential. Otherwise carbon steel should be the primary construction material.

4.69 The molasses clarification section would be purchased as a proprietary plant section. In view of the sulphuric acid treatment and the elevated temperatures most equipment in this section should be supplied in grade 316 stainless steel 1/.

4.70 Although fermenting vessels have been fabricated from carbon steel, the low pH environment coupled with the need to ensure hygienic operation leads to the conclusion that grade 304 stainless steel is the preferable construction material for the fermenters and centrifuge. Fibreglass would be an alternative for the fermenters but this would probably show no cost advantage over grade 304 stainless steel.

4.71 Grade 316 stainless steel is recommended for the yeast treatment vessels where the pH may be as low as 2.5-3.0 following sulphuric acid treatment.

4.72 The fermented wash feed for the distillation plant has a pH of about 4.5. The feed tanks and pipeline as far as the final preheater should therefore be of grade 304 stainless steel. The elevated temperatures in the final preheater and the first distillation column dictate the use of grade 316 stainless steel.

4.73 The other distillation columns and associated equipment are essentially fed by a stream of composition 95% ethanol, 5% water. This derives from the condensed vapours of the first distillation column, which are not acidic. It is therefore satisfactory to use carbon steel for their construction as the ethanol is not required for pharmaceutical or potable purposes.

5. PROJECT OPTIONS

5.01 The principal options for an ethanol distillery are therefore:

a) plant operating during the crop season only with a daily production rate of 107 000 ℓ/d of ethanol;

1/ Stainless steel grades are as defined in B S 3605: 1973.

b) plant operating throughout the year producing 50 000 ℓ/d of ethanol;

c) extension of the Beau Plan potable alcohol distillery, commissioned in 1980, to produce 50 000 ℓ/d of anhydrous ethanol; and

d) extension of Beau Plan to 70 000 ℓ/d.

The third option means foregoing the production of 20 000 ℓ/d of potable alcohol. This would probably be made up by Medine and St Antoine, although alterations and some expansion would be necessary. The capital and operating costs of the fourth option are not materially less than those of the second, and they are not examined.

5.02 There follows a review of available technology followed by more detailed consideration of the design of a 107 000 ℓ/d distillery. Much of the general information presented will of course also be applicable to a 50 000 ℓ/d plant. The Beau Plan option is examined in general terms only. In all cases it is assumed that the vinasse will be returned to the irrigation water. However, the biogas from vinasse option will be examined in the financial analysis, (Section 9), and all options in Section 10, energy considerations.

6. OPTION A: A PLANT OPERATING DURING THE CANE HARVESTING SEASON PRODUCING 107 000 ℓ/DAY

Design considerations

6.01 Choice of technology The detailed reasoning behind the recommendations for the most appropriate technology for each plant section was presented in Section 4. For completeness the choice of processes is summarised below:

a) clarification and pasteurisation of molasses to be effected before fermentation;

b) rapid batch fermentation utilising high yeast concentrations, external cooling of fermenting vessels, centrifuging and recycling of yeast;

c) distillation columns to be controlled at different operating pressures to achieve a reasonable degree of steam economy; and

d) vinasse to be cooled and delivered to irrigation system.

6.02 Molasses composition The average total sugars content of molasses in Mauritius varied from 46-49% in 1971-80. The average for the non-disaster years was 48.14%. In 1979, total sugars at the individual factories varied from 43% to 53% with an average of 48.44% (para 3.02 and End Table 2). These variations are caused by differences in the characteristics of the cane because of differing varieties, climatic conditions, or the time of season in which the cane is harvested. Additionally, the efficiency of the sugar factory's mill extraction and particularly boiling house recovery will affect the sugars content of the molasses. Fermentable sugars (ie sugars capable of being fermented to alcohol) are related to total sugars, the relationship depending on the relative amounts of sucrose, and reducing sugars in total sugars.

6.03 The following table shows how the maximum theoretical yield of alcohol from molasses varies with the fermentable sugar content.

Fermentable sugars content of molasses % w/w	Theoretical yield of ethanol ℓ/t molasses
42	272
44	285
46	297
48	310
50	323

It is assumed that, by careful selection, reasonable quality molasses can be obtained as the feedstock for the ethanol distillery. As a basis for design of the distillery an average fermentable sugars content of 48% has been used.

6.04 Distillery efficiency The yield of ethanol from molasses will be less than the theoretical yield because of processing losses in several sections of the plant. A small quantity of fermentable sugars will be lost in the mud and precipitates separated from the molasses by the clarification process. In practice, with a well operated plant, sugar losses from the clarification section should be less than 1.5%. With the combination of high yeast concentrations and short fermentation times the effective conversion of fermentable sugars to ethanol will be in the region of 90%.

6.05 Losses of ethanol from the distillation section will be measurable from the following areas:

a)	with vinasse	2.0%
b)	with heads product	7.0%
c)	with fusel oils	1.0%
d)	vent losses	1.0%
Total distillation losses		11.0%

If the fusel oils are blended with ethanol the higher molecular weight alcohols make a contribution to the total fuel output of the distillery. The output of fuel is increased by 3.5%. In this case the effective loss of ethanol from the distillation section is only 7.5%.

6.06 Summary of plant losses and ethanol yields The yield of ethanol from molasses is lower than the theoretical yield by the following factors:

Loss of fermentable sugar during clarification	1.5%
Loss of ethanol due to incomplete fermentation	10.0%
Loss of ethanol from distillation plant	7.5%.

Using these factors the followed data are derived:

Fermentable sugars content of molasses % w/w	Practical yield of ethanol £/t molasses	For 107 000 ℓ/d plant Molasses t/d	For 107 000 ℓ/d plant Molasses t/y
42	220	486	65 124
44	231	463	62 042
46	241	444	59 496
48	252	425	56 795
50	262	408	54 672

6.07 Basis of design The following parameters have been used as the basis of design for a 107 000 ℓ/d ethanol plant operating for 134 days each year:

Average fermentable sugars content of molasses	48.0% w/w
Yield of ethanol from molasses	252 ℓ/t
Molasses requirements per day	425 t/d or 57 000 t/y
Plant utilisation	7 days per week 134 days per year

6.08 Cooling water The cooling water requirement for the distillery is 36 000 m^3/d (0.41 cumec). A detailed study of a possible location for the distillery is beyond the scope of this report. It is unlikely that a site, when selected, will be in a position to supply 36 000 m^3/d of cooling water from the irrigation on a once through basis. The project estimate therefore includes an induced draught cooling tower and associated pumps. Evaporation losses, which will require making up, amount to 1 100 m^3/d. If, in the event, a cooling tower installation is found to be unnecessary its cost of Rs2.55 M ($270 000) could be deleted from the project capital cost.

6.09 Steam supply The distillery would be supplied with steam from the sugar factory at a pressure of 5 bar A during the crop harvesting season.

6.10 Process water It is assumed that an adequate supply of clean, filtered water is available for diluting the molasses and for various washing operations for the centrifuges. Approximately 860 m^3/d of process water will be required.

Process description

(See Figure 1, following page 33 for layout drawing).

6.11 Molasses clarification A mixing pump meters and controls the dilution of the raw molasses in one operation. The diluted molasses is acidified with sulphuric acid and heated to 60°C in a plate heat exchanger. It is then brought up to the pasteurising temperature of 85° to 95°C by direct injection of steam in a steam jet heater. The molasses remains for several seconds at this temperature in a holding cell.

6.12 The molasses passes to a release tank from which it is pumped to a plate heat exchanger for cooling. The cooled pasteurised molasses enters a rotary brush strainer and cyclone for removal of sand and larger solid particles. The remaining sulphate precipitate is removed in a centrifugal separator, the timing sequence of which is controlled automatically.

6.13 The underflow from the centrifuge is delivered to a washing vessel where the mud is washed with water. The diluted mud flows under gravity to a decanter for concentration and recovery of associated sugars. The clarified molasses is transferred from the centrifuge to the fermenting vessels.

6.14 <u>Fermentation</u> Each fermenting vessel is filled over a period of about 4 hours while recycled yeast is being added so that the reaction begins immediately. The yeast concentration in the fermenters is high, about 15 g/ℓ, and fermentation is complete within 16 hours. The considerable heat of fermentation (140 kcal/kg of sugar) is removed by external recirculation through plate heat exchangers. This proven system gives good temperature control, maintaining the temperature of the fermenting vessels close to the optimum of 32°C. The carbon dioxide generated is vented from the top of the fermenters.

6.15 When fermentation is complete the yeast is separated from the fermented wash in a nozzle type centrifuge, and the wash is pumped to the distillation feed tanks. The yeast cream is washed with sulphuric acid to maintain hygienic conditions and treated with ammonium sulphate and phospate nutrients before being dosed into the next fermenting batch.

6.16 Twelve fermenting vessels of 120 m^3 capacity are required for a 107 000 ℓ/d ethanol plant. An additional fermenting vessel is provided so that each vessel may be periodically taken out of service for cleaning. A tenth fermenter is included which is fitted with an air sparge to enable this vessel to be utilised for rapidly growing a new culture of yeast under aerobic conditions.

6.17 <u>Distillation</u> The distillation section consists of four columns; an analysing/rectifying column, heads column, dehydration column and entrainer recovery column. The fermented wash is pumped from the distillation feed tanks to the analysing column via a series of preheaters. A steam heater is provided to bring the feed to the correct temperature during start-up when heat cannot be recovered from other exchangers. Any carbon dioxide dissolved in the feed is flashed off in a vapour disengagement vessel before entering the column.

6.18 The analysing/rectifying column operates under a controlled top pressure of 3 bar A and is heated by direct steam injection. The section of the column below the feed strips ethanol from the fermented wash to produce vinasse, the ethanol-free bottom product. This will contain all the inorganic and organic solids originally present in the fermented wash. The vinasse is pumped to a disposal point via a cooler.

6.19 The top section of the analysing/rectifying column rectifies the ethanol to produce a vapour product of 95% v/v ethanol. Some of the vapour is fed to the heads column where lighter boiling components such as acetaldehyde are concentrated. These are condensed, cooled and pumped to storage. It is not possible to separate completely the light components from the ethanol, and about 7% of ethanol produced will be lost in the heads product. The ethanol recovered from the base of the heads column is recycled to the analysing column.

6.20 Vapours from the analysing/rectifying column which are under pressure and at a temperature of over 130°C are used to provide heat for the dehydration column by condensing in the dehydration column reboiler. Any vapours not condensed here are condensed in a final condenser, and all condensate is collected in the analyser reflux drum. A proportion of the condensed 95% alcohol is returned to provide reflux for the analysing/rectifying column and remainder is pumped to the dehydration column.

6.21 In the dehydration column the 95% ethanol stream is distilled with an entrainer, benzene, used to remove the remaining 5% water which cannot be separated by conventional distillation. The bottom product from the dehydration column is anhydrous ethanol containing at least 99.7% w/w ethanol. This is cooled and transferred to the storage/blending tanks.

6.22 The vapours from the top of the dehydration column contain benzene, ethanol and water. These are condensed and decanted hot. The decanter forms an integral part of the dehydration column. Two layers separate out in the decanter. One is rich in benzene (80%) and is refluxed in the dehydration column. The other aqueous layer containing 6% benzene and some ethanol is fed to the entrainer recovery column in which the benzene concentration is increased. A benzene rich top product is pumped back to the decanter. The bottom product of this column is a dilute ethanol stream which is returned to the feed tanks for reprocessing.

6.23 Storage Two molasses storage tanks of 3 000 m^3 capacity each are provided to permit storage of up to 30 days feedstock. Ethanol product is pumped from the dehydration column to one of two 200 m^3 storage/blending tanks. These are included to allow quality checks on each day's production to be made and for fusel oils and denaturant to be blended before the product is transferred to the principal storage tanks. Four 2 500 m^3 ethanol product tanks are included to enable one month's production to be stored at the distillery. Storage tanks of 100 m^3 capacity each provide one month's storage of heads product and fusel oils. A tank to hold the equivalent of two road tankers of gasoline for use as denaturant is also provided.

Service requirements

6.24 Service requirements The following services are required in a 107 000 ℓ/d plant.

- Steam, at 5 bar A saturated, from adjacent sugar factory.

- Cooling water, supplied at 30°C from cooling tower and returned to cooling tower at 38°C max.
- Cooling tower make-up water, clean, filtered to make up evaporation losses of approximately 3%
- Process water, clean, filtered for molasses dilution, centrifuge washing and dissolving nutrients.
- Electricity, 415/440 volts, 50 Hz, 3 phase.

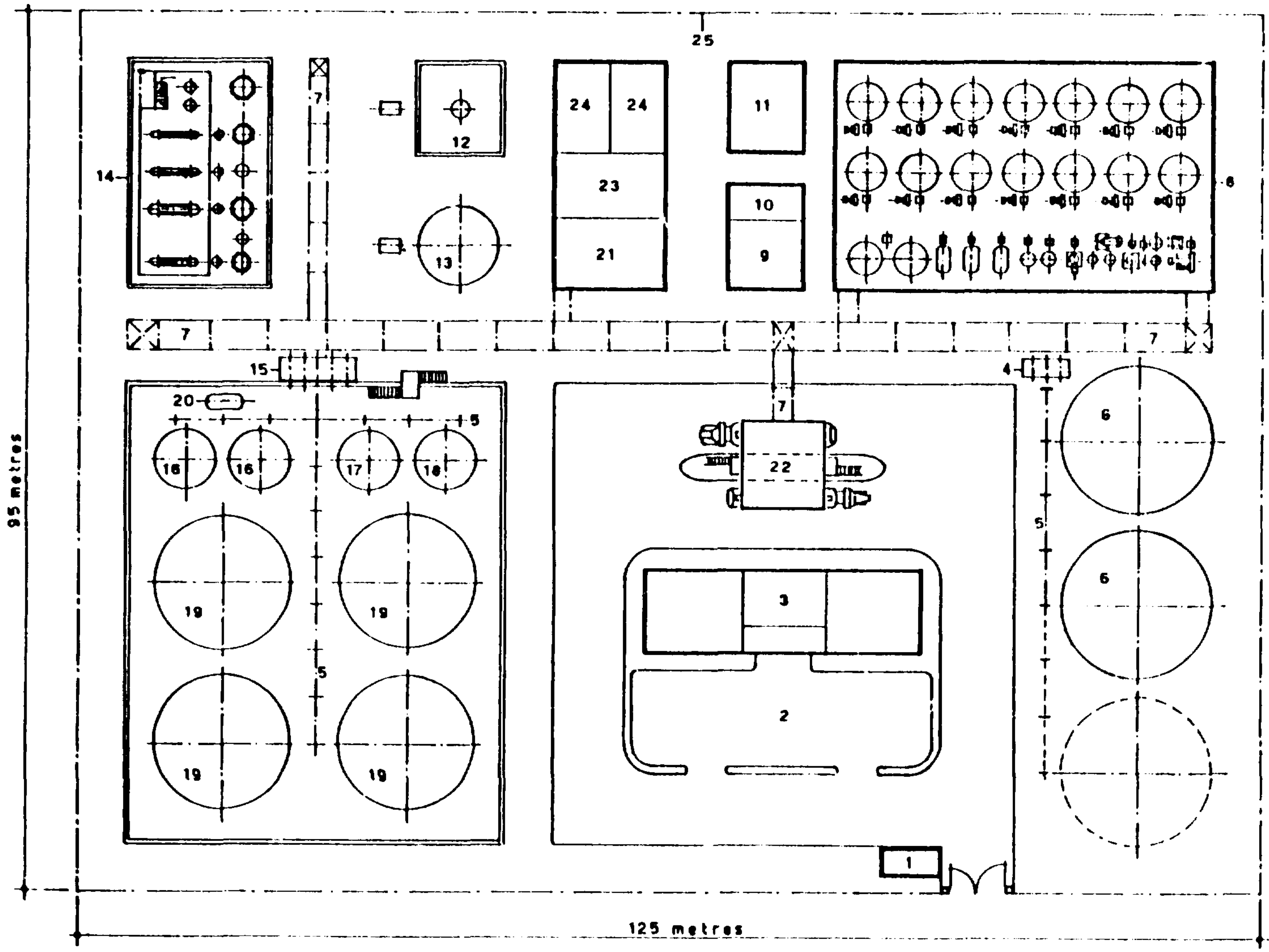
		Consumption per litre of ethanol	Consumption per day
Steam:	Molasses pasteurisation	1.2 kg	130 t
	Distillation	3.0 kg	320 t
		4.2 kg	450 t
Cooling water	Molasses pasteurisation	4 ℓ	430 m^3
	Fermentation	144 ℓ	1 540 m^3
	Distillation	188 ℓ	20 120 m^3
		336 ℓ	36 000 m^3
Cooling Tower Make-up Water:		10 ℓ	1 100 m^3
Process Water:	Molasses dilution	6.8 ℓ	730 m^3
	Nutrients dilution	0.1 ℓ	10 m^3
	Centrifuge washing	1.1 ℓ	120 m^3
	Total	8.0 ℓ	860 m^3
Fuel Oil (Options B and C only):		0.34 ℓ	

Electricity	Installed Power (kW)	Absorbed power per litre of ethanol (kWh)	Absorbed power per day (kWh)
Molasses Clarification	125	0.038	1 920
Fermentation	110	0.029	1 440
Distillation	35	0.012	600
Offsites:			
Cooling tower fan & pumps	180 kW	0.058	2 880
Air compressors	15 kW	0.002	120
Storage pumps	35 kW	0.005	240
Cleaning in place	5 kW	Minimal	Minimal
Boiler	30 kW	0.010	480
Total during crop season	505 kW	0.144	7 200

Layout of Ethanol Plant
Capacity: 107,000 litres/day

Fig. 1

LEGEND
1. GATE HOUSE
2. CAR PARK
3. OFFICES, LABORATORY & AMENITIES
4. MOLASSES UNLOADING & TRANSFER PUMPS
5. PIPETRACKS
6. MOLASSES STORAGE TANKS
7. ELEVATED PIPERACKS
8. CLARIFICATION & FERMENTATION BUILDING
9. CONTROL ROOM
10. SWITCHROOM
11. C.I.P. PLANT
12. COOLING TOWER, SUMP & PUMP
13. PROCESS WATER TANK & PUMP
14. DISTILLATION PLANT
15. PRODUCT & TRANSFER PUMPS
16. ETHANOL BLEND TANKS
17. FUSEL OILS STORAGE TANK
18. HEADS STORAGE TANK
19. ETHANOL STORAGE TANKS
20. DENATURANT TANK
21. COMPRESSOR HOUSE
22. TANKER LOADING CANOPY
23. STORES & SERVICES
24. WORKSHOPS
25. BOUNDARY FENCE



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Chemicals consumption

6.25 The following chemicals would be consumed by a 107 000 ℓ/d plant.

	Consumption per litre of ethanol	Consumption per day
Sulphuric acid, 98% for adjustment of molasses pH and treatment of recycled yeast	12 g	1 284 kg
Yeast nutrients		
Ammonium sulphate	5.6 g	600 kg
Mono ammonium phosphate	2.8 g	300 kg
Benzene		
Entrainer for distillation plant	0.13 mℓ	14.1 ℓ
Denaturant		
Gasoline at 3% addition to ethanol product	30 mℓ	3 210 ℓ

Unit cost of raw materials and utilities

6.26 Raw materials (all costs expressed as delivered to distillery)

Molasses	Rs	600/t
Sulphuric acid, 98%	Rs	7 890/t
Ammonium sulphate	Rs	2 305/t
Mono ammonium phosphate	Rs	9 790/t
Benzene	Rs	4.85/ℓ
Denaturant, gasoline	Rs	0.33/ℓ (transport cost only)

Utilities

Steam (ex sugar factory)	Rs	35/t
Fuel oil	Rs	3.56/ℓ (Options B and C only)
Process water	Rs	0.1/m^3
Cooling water make-up	Rs	0.1/m^3
Electricity	Rs	0.96/kWh

Capital cost estimate

6.27 Capital costs are estimated as follows:

Capital cost estimate

	Foreign Exchange component (Rs'000)	Local component (Rs'000)	Total cost (Rs'000)
Clarification	6 934	65	6 999
Fermentation	11 284	1 495	12 779
Distillation	6 632	2 010	8 642
Storage	7 460	430	7 890
Offsites	12 360	145	12 505
Total materials	44 760	4 145	48 815
Delivery and cif charges	7 590	420	8 010
Civils and buildings	10 971	2 320	13 291
Construction	1 478	8 350	9 818
Engineering/commissioning	12 000	-	12 000
Tankers	1 655	160	1 815
	78 364	15 395	93 759
Contingencies	7 836	1 540	9 376
Total	86 200	16 935	103 135
$'000	8 410	1 652	10 062
	84%	16%	100%

Variable operating costs

6.28 Variable costs for a 107 000 ℓ/d plant are:

Variable operating costs

	Daily Usage	Daily Cost (Rs)	Cost of ethanol Rs/ℓ
Raw material			
Molasses(48% ferm sugar)	425 t	255 000	2.383
Chemicals:			
Sulphuric acid (98%)	1 284 kg	10 131	0.095
Ammonium sulphate	600 kg	1 383	0.013
Mono ammonium phosphate	300 kg	2 937	0.028
Benzene	14.1 ℓ	68	Neg
Denaturant (transport cost only)	3 210 ℓ	106	Neg
Total chemicals cost		14 625	0.136
Utilities			
Steam (ex sugar factory)	450 t	15 750	0.147
Process water	860 m^3	86	0.001
Electricity	10 800 kWh	10 368	0.097
Cooling water make-up	1 100 m^3	110	0.001
Total utilities cost		26 314	0.246
Transport	107 000 ℓ	3 531	0.033
Total variable costs		299 470	2.798
	$	29 217	0.27

6.29 Variable costs during first year of operation An allowance must be made for additional operating costs which may be incurred during the first year of operation of the distillery. In this period the management and operating staff will be familiarising themselves with the procedures for operating the plant. It is probable that ethanol yields and consumption of utilities and services will be worse than in subsequent years when any initial operating difficulties will have been solved.

It is suggested that an additional 15% be included for the variable operating costs for the first year of the plant's life and that a production rate of two-thirds of the design rate (ie 72 000 ℓ/d) should be used for this period.

First year variable costs,
During crop season Rs2.798 x 1.15 = Rs3.218/ℓ ethanol ($0.28)

Summary of capital and operating costs

6.30 The following summarises the capital and operating costs of a 107 000 ℓ/d plant.

Summary of capital and operating costs for 107 000 ℓ/d ethanol plant

Capital Costs	Rs'000	$'000
Installed plant cost	103 135	10 062
Working Capital - start-up costs	15 000	1 463
- spares	4 125	402
Total capital investment	122 260	11 927
Fixed Operating Costs	**Rs'000/y**	**$'000/y**
Salaries, wages, etc	1 350	136
Maintenance - process plant (5%)	3 885	379
- buildings, civils (2%)	509	50
	5 744	561
Variable Operating Costs		
1st year:		
134 days @ 72 000 ℓ/d @ Rs2.798 x 1.15/ℓ	31 044	3 029
2nd and subsequent years		
134 days @ 107 000 ℓ/d @ Rs2.798/ℓ	40 118	3 914
Total Operating Costs		
1st year	36 788	3 590
2nd and subsequent years	45 862	4 475

6.31 If an anaerobic vinasse digester is used to dispose of virasse, costs become:

	Daily Usage	Daily Cost (Rs)	Cost of ethanol Rs/ℓ
Utilities			
Steam, ex sugar factory	205 t	7 175	0.067
Process water	860 m^3	86	0.001
Electricity	12 050 kWh	11 568	0.108
Cooling water make-up	1 100 m^3	110	0.001
Total utilities cost		18 939	0.176
		$1 848	$0.017

Unit variable costs would be Rs2.728/ℓ. Capital costs would be Rs149.66 M ($14.8 M - paras 4.58 and 6.30).

Variable operating costs:

1st year	Rs'000/y	$'000/y
134 days @ 72 000 ℓ/d @ Rs2.728 x 1.15/ℓ	30 267	2 953
2nd and subsequent years		
134 days @ 107 000 ℓ/d @ Rs2.728/ℓ	39 114	3 816
Total operating costs		
1st year	36 041	3 516
2nd and subsequent years	44 888	4 379

6.32 Total operating costs for Option A for the second and subsequent years including depreciation (on a 25 year life) and interest are:

Without vinasse digester

	Rs'000/y	Rs/ℓ	$'000/y	$/y
Costs	45 862	3.199	4 475	0.31
Depreciation 4%	4 890	0.341	4 771	0.03
Interest 10%	12 226	0.853	1 193	0.08
	62 978	4.393	10 439	0.42

With vinasse digester

	Rs'000/y	Rs/ℓ	$'000/y	$/y
Costs	44 888	3.131	4 379	0.31
Depreciation 4%	5 986	0.417	584	0.04
Interest 10%	14 966	1.044	1 460	0.10
	65 840	4.592	6 423	0.45

OPTION B: A PLANT OPERATING THROUGHOUT THE YEAR PRODUCING 50 000 ℓ/d

Design considerations

7.01 The explanations for the selection of the various design parameters are similar to those for a 107 000 ℓ/d distillery. The conclusions relating to the basis of design for a 50 000 ℓ/d distillery are presented below.

Daily production rate	50 000 ℓ/d ethanol
Period of operation	134 days during crop season 166 days out-of-crop
Fermentable sugars content of molasses	48.0% w/w
Ethanol yield/tonne of molasses	252 ℓ/t
Molasses required/day	200 t/d
Molasses required/year	60 000 t/y

Service requirements

7.02 The following services are required in a 50 000 ℓ/d plant

- Steam, at 5 bar A, dry, saturated from adjacent sugar factory during harvest season and from oil-fired boilers out-of-crop.

- Cooling water, supplied at 30°C from cooling tower and returned to cooling tower at 38°C max.

- Cooling tower make-up water, clean, filtered to make up evaporation losses of approximately 3%.

- Process water, clean filtered for molasses dilution, centrifuge washing and dissolving nutrients.

- Fuel oil, calorific value approximately 10 000 kcal/kg, for steam generation in out-of-crop season.

- Electricity, 415/440 volts, 50 Hz, 3 phase.

Details of the consumption of services per litre of ethanol produced are the same as those in para 6.24. Total out-of-crop season use of electricity would be 0.154 kWh absorbed power/ℓ ethanol and 7 680 kWh absorbed power/d.

Chemical consumption

7.03 The following chemicals would be consumed by a 50 000 ℓ/d plant

	Consumption per litre of ethanol	Consumption per day
Sulphuric acid, 98% for adjustment of molasses pH and treatment of recycled yeast	12 g	600 kg
Yeast Nutrients		
Ammonium sulphate	5.6 g	280 kg
Mono ammonium phosphate	2.8 g	140 kg
Benzene Entrainer for distillation plant	0.13 mℓ	6.6 ℓ
Denaturant Gasoline at 3% addition to ethanol product.	30 mℓ	1 500 ℓ

Capital cost estimate

7.04 The capital costs of a 50 000 ℓ/d plant are estimated as follows:

	Foreign Exchange Component	Local	Total Cost
	Rs'000		
Clarification	4 392	42	4 434
Fermentation	6 946	920	7 866
Distillation	4 203	1 273	5 476
Storage	10 829	612	11 441
Offsites	9 044	223	9 267
Total Materials	35 414	3 070	38 484
Delivery and cif charges	6 018	330	6 348
Civils and Buildings	8 926	1 900	10 826
Construction	1 212	6 550	7 762
Engineering/Commissioning	9 458	-	9 458
Tanker	828	80	908
	61 856	11 930	73 786
Contingencies	6 186	1 193	7 379
Total	68 042	13 123	81 165
$'000	6 638	1 280	7 918
	84%	16%	100%

Variable operating costs

7.05 The variable operating costs are as follows:

	Daily Usage	Daily Cost (Rs)	Cost of ethanol Rs/ℓ
Raw material			
Molasses(48% ferm sugar)	200 t	120 000	2.400
Chemicals:			
Sulphuric acid (98%)	600 kg	4 735	0.095
Ammonium sulphate	280 kg	646	0.013
Mono ammonium phosphate	140 kg	1 370	0.028
Benzene	6.6 ℓ	32	Neg
Denaturant (transport only)	1 500 ℓ	50	Neg
Total chemicals cost		6 833	0.136

Utilities

1 During Crop Season			
Steam (ex sugar factory)	210 t	7 350	0.147
Process water	400 m^3	40	0.001
Electricity	7 200 kWh	6 912	0.138
Cooling water make-up	500 m^3	50	0.001
Total utilities cost		14 352	0.287
2 Out-of-crop season			
Fuel oil	16 800 ℓ	59 783	1.196
Process water	400 m^3	40	0.001
Electricity	7 680 kWh	7 373	0.138
Cooling Water make-up	500 m^3	50	0.001
Total utilities cost		67 246	1.345
Transport	50 000 ℓ	1 650	0.033

Total variable costs:

1 During crop season Rs142 835/d ($13 935/d) Rs2.856/ℓ ($0.28/ℓ)

2 Out-of-crop season Rs195 729/d ($19 096/d) Rs3.914/ℓ ($0.38/ℓ)

Summary of capital and operating costs

7.06 The following summarises the capital and operating costs of a 50 000 ℓ/d plant.

Capital Costs	Rs'000	$'000
Installed plant cost	81 165	91852
Working Capital - start-up costs	7 500	732
- spares	3 247	316
Total capital investment	91 912	8 966

Fixed Operating Costs	Rs/'000/y	$'000/y
Salaries, wages, etc	1 350	132
Maintenance - process plant (5%)	3 506	346
- buildings, civils (2%)	409	40
	5 265	514

Variable Operating Costs

1st year:		
During crop		
134 days @ 33 500 ℓ/d @ Rs2.856 x 1.15/ℓ	14 854	1 449
Out-of-crop		
166 days @ 33 500 ℓ/d @ Rs3.914 x 1.15/ℓ	25 031	2 442
Total variable costs	39 885	3 891

2nd and subsequent years:		
During crop		
134 days @ 50 000 ℓ/d @ Rs2.856	19 135	1 867
Out-of-crop		
166 days @ 50 000 ℓ/d @ Rs3.914	32 486	3 169
Total variable costs	51 621	5 036
Total operating costs		
1st year	45 150	4 405
2nd and subsequent years	56 886	5 550

7.07 Total operating costs for Option B for the second and subsequent years including depreciation and interest are:

	Rs'000/y	Rs/ℓ	$'000/y	$/y
Costs	56 886	3.792	5 550	0.37
Depreciation 4%	3 676	0.245	359	0.02
Interest 10%	9 191	0.613	897	0.06
	69 753	4.650	6 806	0.45

OPTION C: A 30 000 ℓ/d EXTENSION TO THE EXISTING DISTILLERY AT BEAU PLAN

8.01 The distillery at Beau Plan has a capacity of 20 000 ℓ/d of ethanol, currently used for potable alcohol production. With some minor charges to the pipework the four distillation columns could be used to distil anhydrous ethanol suitable for blending with gasoline.

8.02 To extend the distillery's capacity to 50 000 ℓ/d of anhydrous ethanol would essentially entail the construction of a parallel plant with an output of 30 000 ℓ/d of ethanol. A development of this type would require the lowest capital expenditure, but would of course prohibit the production of any potable alcohol simultaneously with 50 000 ℓ/d of anhydrous ethanol.

8.03 The following is an outline of the new plant required for this extension:

a) Addition of a parallel line of molasses clarification and pasteurisation plant to handle 5 t/h of molasses.

b) Additional fermenting vessels to increase the fermenting section throughput from 20 000 ℓ/d to 50 000 ℓ/d, plus a further yeast centrifuge.

c) A distillation train with four columns with a capacity of 30 000 ℓ/d.

d) An increase in molasses storage capacity from 30 days to 160 days to enable the distillery to operate throughout the year.

e) Additional storage for ethanol product, heads, fusel oils and denaturant.

f) Extension of the facilities for steam generation cooling water supply, process water supply etc to provide adequate utilities for the increased plant capacity.

8.04 A capital cost estimate for extension to Beau Plan has been prepared, but it must be pointed out that its accuracy must be limited since a detailed study of the duties and capacities of the equipment at the Beau Plan distillery was outside the terms of reference of this report.

	Foreign Exchange component (Rs'000)	Local component (Rs'000)	Total cost (Rs'000)
Estimate of cost of modifications to existing distillation plant	-	425	425
New plant			
Clarification	3 542	34	3 576
Fermentation	5 116	692	5 808
Distillation	3 384	1 082	4 466
Storage	7 412	475	7 887
Offsites	6 898	175	7 073
	26 352	2 883	29 235
Delivery and cif charges	4 481	248	4 729
Civils and buildings	6 688	1 415	8 103
Construction	1 123	4 740	5 863
Engineering and commissioning	7 921	-	7 921
Tanker	828	80	908
	47 393	9 366	56 759
Contingency	4 739	937	5 676
Total	52 132	10 303	62 435
$	5 086	1 005	6 091
	84%	16%	100%

8.05 For the purposes of this study, the operating costs have been assumed to be identical to those in Option B, the new 50 000 ℓ/d plant. Total operating costs for the extra 30 000 ℓ/d produced by Option C including depreciation and interest are:

	Rs'000/y	Rs/ℓ	$'000/y	$/y
Costs	37 924	3.792	3 700	0.37
Depreciation 4%	2 497	0.250	244	0.02
Interest 10%	6 243	0.624	609	0.06
	46 664	4.666	4 553	0.45

9. FINANCIAL AND ECONOMIC ANALYSIS OF OPTIONS

9.01 Operating costs Costs of producing ethanol by the three options, including depreciation (over 25 years) and interest are:

	Option	Rs/ℓ	US¢/ℓ
107 000 ℓ/d (crop season only)	A	4.393	42
50 000 ℓ/d (year round)	B	4.650	45
30 000 ℓ/d extension to Beau Plan	C	4.666	45
107 000 ℓ/d with vinasse digester	A	4.592	45

9.02 Rates of return The internal rates of return (IRR) are as shown below at current prices and on the assumption that the prices of both gasoline and molasses will rise by 3%/y in real terms whilst other costs remain steady. Section 3, Appendix 11 describes the analyses in more detail, and End Tables 1-3, Appendix 11, give cash forecasts for the three Options.

	Option	IRR At current prices	IRR Gasoline and molasses + 3%/y
107 000 ℓ/d plant	A	1.1	7.8
50 000 ℓ/d plant	B	0	2.9
30 000 ℓ/d extension to Beau Plan	C	0	0

From these rates of return we conclude that Option A is superior to the other two. The extra capital cost of the larger distillery is offset by the lower unit costs of utilities during the crop season and to a much greater extent by not incurring the much higher out-of-crop costs. Th_ extension of Beau Plan fails because of the loss of its revenue from potable alcohol.

The second purpose of the analyses is to decide whether the IRR of the highest ranking option is sufficient to recommend acceptance. At current prices this would certainly not be the case. On the assumption that the prices of both gasoline and molasses will rise by 3%/y in real terms whilst other costs remain steady, only Option A approaches present rates of interest on loans for development. However non-financial considerations may make Option A appear more attractive.

9.03 Sensitivity The returns are sensitive to the assumptions made about:

a) the levels of molasses prices - cost variations of 15% in either direction are considered (paras 3.12-3.14, Appendix 10);

b) whether or not molasses prices will increase in real terms with gasoline prices;

c) whether gasoline prices and/or molasses prices will start to rise in real terms only after the present recession is over;

d) the date of commissioning.

The returns obtained on Option A under these varying assumptions are as follows:

Base rate	7.8%
Molasses price at the low end of the range	12.5%
- at the high end of the range	2.0%
Gasoline prices alone increasing 3% in real terms	14.0%
Gasoline and molasses prices steady in real terms until 1985, then rising 3%/y	5.9%
Plant construction in 1990, assumptions otherwise as in base rate	12.5%

None of these rates of return would justify construction of a plant given the present high rates of interest.

A detailed discussion of these assumptions, and a table of the rates of return on the assumptions at the full range of molasses prices are provided in Appendix 11.

Economic returns

9.04 The financial model considers the distillery as a complete entity in the economy of Mauritius, using border prices for its principal inputs - plant and molasses - and its output - ethanol. Indeed of the other inputs, only steam, water and labour can be said to be wholly domestic. Acordingly the foreign exchange valuation factor is applied to all outputs and almost all inputs. No adjustment needs to be made for labour costs, since all labour would be skilled or semi-skilled. No other parts of the economy, either on the input or on the output side, are affected by the switch from gasoline to the ethanol mixture. Government would however, lose the export duty on molasses (currently 12.1%).

9.05 For the reasons given above, the economic returns are not materially higher than the financial ones, and do not affect the ranking of the options. The economic rate of return in Option A is 8.5%.

10. ENERGY CONSIDERATIONS

10.01 The primary function of a fuel ethanol plant is the production of a liquid fuel which can be readily blended with imported gasoline. It is therefore important to compare the energy contained in the ethanol product with the energy requirement of the distillery. A plant which consumes more energy than is contained in the ethanol is unlikely to be viable unless an inexpensive low grade fuel input is available.

10.02 Energy generation Energy generated by the combustion of 107 000 ℓ/d of ethanol (84.5 t/d) with a calorific value of 6 450 kcal/kg is 545 M kcal/d. The energy requirements of the distillery in terms of steam and electricity depend on the method of vinasse treatment:

(M kcal/d)	Net energy input as steam	Energy input as electricity	Total energy input
Vinasse disposal on fields	295.5	9.3	304.8
Vinasse evaporation	505.7	13.7	519.4
Vinasse incineration	236.3	17.2	253.5
Anaerobic digestion of vinasse	134.6	10.4	145.0

The energy ratio is defined as $\frac{\text{Energy produced by distillery}}{\text{energy input to distillery}}$

Net energy generated is defined as energy generated minus the total energy input.

For the different methods of vinasse treatment the values of these for a 107 000 ℓ/d distillery are:

	Energy ratio	Net energy generation (M kcal/d)
Vinasse disposal of fields	1.79	240.2
Vinasse evaporation	1.05	25.6
Vinasse incineration	2.15	291.5
Anaerobic digestion of vinasse	3.76	359.1

10.03 Energy returns to capital in Option A are as follows:

	Capital		Energy return on capital	
	Rs'000	$'000	kcal/d/R	kcal/d/$
Vinasse disposal in fields	103 135	10 062	2.33	23.87
Vinasse evaporation	147 135	14 355	0.17	1.74
Vinasse incineration	180 635	17 623	1.61	16.14
Anaerobic digestion of vinasse	130 535	12 735	2.75	27.51

The production of methane by anerobic digestion of vinasse shows an increased energy return of 17% of capital. There is also a financial return; the IRR on the investment in the digester is 3.5%. This return is low in the case of Option A because the methane is replacing cheap steam; it would be higher with Option B, where it would replace high cost fuel oil for 55% of its operation. The IRR on the 107 000 ℓ/d distillery with digester is 6.8%, compared with the base rate of 7.8%. End Table 4, Appendix 11, shows a cash forecast of this option.

10.04 Use of bagasse pellets in Option B The fuel oil used out-of-crop in Option B could be replaced by 15 770 t of bagasse pellets (See Appendix 7A para 7.10). This is 7% of the available pellets. There would obviously be no financial advantage if the opportunity cost of the bagasse is based on fuel oil. If however it is based on coal at an opportunity cost of pellets of Rs310/t ($30.24, para 7.11, Appendix 7A), the IRR on the investment in the distillery and the digester (on the basis used in para 9.01) is 7.6%, marginally below the return on Option A. This takes no account of the electricity foregone by not burning the pellets in a power station.

11. RECOMMENDATIONS

Projects

11.01 The present study shows that no ethanol distillery would be viable in the immediate future, and no recommendations are made for future studies. A pilot plant for vinasse disposal by anaerobic digestion is recommended at Beau Plan, at the following cost:

	Foreign Exchange Component	Local	Total
Rs million	6	1	7
$ million	0.59	0.09	0.68

Coordination

11.02 A Central Energy Planning Committee should be set up with powers to develop and enforce a natural energy policy. It would be responsible to the Authority at ministerial level established to development national exploitation of suarcane by-products industry. Its members would be representatives of the interested ministries, CEB, the gasoline companies, and sugar producers. In the field of ethanol production, it would monitor world market trends of molasses and gasoline, and it would be responsible for deciding whether, and when, to get an ethanol project under way. In the short term it would regulate relationships between the parties (in conjunction with the Cane Millers and Planters Arbitration and Control Board), and would allocate responsibilities for carrying out developments.

END TABLES

Mauritius: consumption of gasoline, 1971-83 End Table 1

	£ million		
	Premium	Regular	Total
Actual			
1971	25.7	5.9	31.6
1972	34.2	4.4	38.6
1973	32.6	5.0	37.6
1974	39.2	4.4	38.6
1975	39.9	4.1	44.0
1976	48.1	4.3	52.4
1977	58.2	4.2	62.4
1978	62.5	4.7	67.2
1979	60.3	4.8	65.1
1980	49.3	4.2	53.5
Forecast			
1981	44.6	3.7	48.3
1982	44.6	3.7	48.3
1983	44.1	3.7	47.8

Source: Shell Company of the Islands Limited, Port Louis.

Mauritius: prices of gasoline 1979-81 End Table 2

	Premium				Regular	
	cif Port Louis			retail	retail	
	Rs/ℓ	Rs/g	Rs/ℓ	Rs/g	Rs/ℓ	Rs/g
4 Jan 1979	0.90	4.07	2.42	11.00	2.25	10.25
13 Jan 1979	1.26	5.75	3.30	15.00	3.13	14.25
24 Oct 1979	1.52	6.91	4.07	18.50	3.74	17.00
5 Nov 1979	1.92	8.72	4.84	22.00	4.62	21.00
1 Mar 1980	2.23	10.15	5.17	23.50	4.95	22.50
19 Jul 1980	2.28	10.37	5.50	25.00	5.33	24.25
6 Dec 1980	2.45	11.14	5.72	26.00	5.55	25.25
1 Jul 1981	2.80	12.72	6.60	30.00	6.49	29.50
(1 Jul 1981 $	0.32	1.47	0.76	3.46	0.75	3.40)

Sources: Oil companies operating in Mauritius.

Mauritius: numbers of motor vehicles 1975-80 End Table 3

	New registrations	Total registered (end-year)
1975	5 675	43 017
1976	8 461	50 741
1977	9 371	59 670
1978	4 997	64 581
1979	4 913	68 990
1980	3 799	69 829

Source: Central Statistical Office.

APPENDIX 6A

ANNEXES

APPENDIX 6A

ANNEX 1

Equipment schedule for a 107 000 ℓ/d distillery

1. Molasses clarification section
2. Fermentation section
3. Distillation section
4. Storage section
5. Off-sites and ancillary equipment
6. Piping and valves
7. Electrics
8. Instrumentation
9. Civil engineering and buildings

APPENDIX 6A
Annex 1

1. **Molasses Clarification Section**

Item	Description
Feed Preheater/Molasses Cooler	Plate heat exchanger in three sections 316 stainless steel
Steam Heater	Jet type heater 5 bar steam required 316 stainless steel
Molasses/Water Mixing Pump	Rotary piston type Two driving systems for 30 t/h water and 18 t/h molasses variable stroke adjustment, stainless steel
Strainer Feed Pump	60 m^3/h centrifugal stainless steel
Mud Pump	10 m^3/h centrifugal, stainless steel
Rotary Brush Strainer	For separation of coarse solids Capacity approximately 60 m^3/h stainless steel
Hydrocyclone	For desanding molasses Capacity approximately 60 m^3/h stainless steel
Centrifugal Separator	Capacity 55 t/h diluted molasses Fitted with self-cleaning bowl and automatic timing unit stainless steel
Decanter	For concentration and clarification of sludge and separator, stainless steel
Release tank	10 m^3 vertical cylindrical conical base 315 stainless steel
Mud Washing Tank	10 m^3, vertical cylindrical, carbon steel
Holding Cell	To provide six seconds hold-up for pasteurised molasses, 316 stainless steel

APPENDIX 6A
Annex 1

2. Fermentation Section

Item	Description
Fermenter Coolers, 14 off	11 m^2 surface area Plant exchanger type 316 stainless steel
Fermenter Recirculation Pumps 14 off	50 m^3/hr, centrifugal type, stainless steel
Yeast Sludge Pump	25 m^3/hr, positive displacement type, stainless steel
Acidified Yeast Pump	25 m^3/hr, positive displacement type, stainless steel
Sulphuric Acid Pump	1.0 m^3/hr, centrifugal, stainless steel
Distillation Feed Pump	55 m^3/hr, centrifugal type, stainless steel
Yeast Centrifuge	Nozzle type Including rotary brush strainer and defoaming pump, stainless steel
Sulphuric Acid Tank	12 m^3, horizontal cylindrical carbon steel
Nutrients Tank	18 m^3 horizontal cylindrical, Fitted with agitator, carbon steel
Distillation Feed Tanks 2 off	120 m^3, vertical cylindrical, 304 stainless steel
Fermenting Vessels, 14 off	120 m^3, vertical cylindrical, 304 stainless steel
Yeast Treatment Vessels, 2 off	10 m^3 vertical cylindrical Fitted with agitator, 304 stainless steel

3. Distillation section

Item	Description
Analysing/rectifying Column	Fitted with sieve trays 2.2 m diameter, 30 m high, 316 Stainless steel
Heads Column	Fitted with valve trays 1.0 m diameter, 12 m high, carbon steel
Dehydration Column	Fitted with valve trays 2.2 m diameter, 37 m high Includes entrainer decanter, carbon steel
Entrainer Recovery Column	Fitted with valve trays 1.0 m diameter, 8 m high, carbon steel
Steam Feed Preheater	60 m^2 surface area Plate exchanger type, 316 stainless steel
Spent Wash Cooler/ Feed Preheater	100 m^2 surface area Plate exchanger type, 316 stainless steel
Spent Wash Final Cooler	32 m^2 surface area Plate exchanger type, 316 stainless steel
Heads Condenser	10 m^2 surface area Shell and tube exchanger, carbon steel
Heads Vent Cooler	5 m^2 surface area Shell and tube exchanger, carbon steel
Heads Product Cooler	1.2 m^2 surface area Plate exchanger type, 316 stainless steel
Dehydration Column Reboilers 2 off	180 m^2 surface area Vertical callandria type, carbon steel
Analysing Column Final Condenser	50 m^2 surface area Shell and tube exchanger, carbon steel

APPENDIX 6A
Annex 1

Distillation section (cont)

Item	Description
Analysing Column Vent Condenser	10 m^2 surface area Shell and tube exchanger, carbon steel
Ethanol Product Cooler	5 m^2 surface area Plate exchanger type, 316 stainless steel
Dehydration Column Condenser/ Feed Preheater	75 m^3 surface area Shell and tube exchanger 304 stainless steel cubes, carbon steel shell
Dehydration Column Condenser	75 m^2 surface area Shell and tube exchanger, carbon steel
Dehydration Column Vent Cooler	15 m^2 surface area Shell and tube exchanger, carbon steel
Entrainer Column Condenser	32 m^3 surface area Shell and tube exchanger, carbon steel
Entrainer Column Vent Cooler	10 m^2 surface area Shell and tube exchanger, carbon steel
Spent Wash Pump	65 m^3/h, centrifugal, stainless steel
Heads Column Recycle Pump	2 m^3/h, centrifugal, carbon steel
Analyser Column Reflux Pump	25 m^3/h, centrifugal, carbon steel
Ethanol Product Pump	5.0 m^3/h, centrifugal, carbon steel
Dehydration Column Reflux Pump	25 m^3/h, centrifugal, carbon steel
Entrainer Column Recycle Pump	2 m^3/h, centrifugal, carbon steel
Benzene Pump	Variable stroke metering pump, carbon steel
Fusel Oils Pump	0.5 m^3/h centrifugal, carbon steel

Distillation section (cont)

Item	Description
Benzene Tank	2.5 m^3, horizontal cylindrical, carbon steel
Analysing Column Reflux Drum	2.5 m^3 vertical cylindrical, carbon steel
Heads Column Reflux Drum	0.5 m^3, vertical cylindrical, carbon steel
Dehydration Column Reflux Drum	2.5 m^3, vertical cylindrical, carbon steel
Fusel Oils Decanter	0.5 m^3, vertical cylindrical, carbon steel
Entrainer Column Reflux Drum	0.5 m^3, vertical cylindrical, carbon steel
Vapour disengagement Vessel	2.5 m^3, vertical cylindrical, carbon steel

4. Storage Section

Molasses Offloading/Feed Pumps (2 off)	20 m^3/h, positive displacement pump, carbon steel
Ethanol Product Pumps (2 off)	30 m^3/h, centrifugal, carbon steel
Heads Product Pump	10 m^3/h, centrifugal, carbon steel
Fusel Oils Product Pump	10 m^3/h, centrifugal, carbon steel
Denaturant Pump	10 m^3/h centrifugal, carbon steel
Molasses Storage Tanks (2 off)	3 000 m^3, site erected tanks, carbon steel
Ethanol Storage/Blending Tanks (2 off)	200 m^3 vertical cylindrical, carbon steel

Distillation section (cont)

Ethanol Storage Tanks (4 off)	2 500 m^3, site erected tanks, carbon steel
Heads Storage Tank	200 m^3 vertical cylindrical, carbon steel
Fusel Oils Storage Tank	200 m^3 vertical cylindrical, carbon steel
Denaturant Storage Tank	20 m^3 horizontal cylindrical, carbon steel

5. Offsites and ancillary equipment

Cooling Tower Installation	1 500 m^3/h capacity Induced draught type Plastic packing Includes circulation pumps
Process Water Tank	425 m^3 vertical cylindrical, carbon steel.
Feed Water Pump	60 m^2/hr, centrifugal, carbon steel
Instrument Air Compressor	100 N m^3/hr at 6 bar Includes filter, dryer, receiver
Plant Air Compressor for Yeast Propagation	150 N m^3/hr at 6 bar
Road Tanker Loading/ Off-Loading Station	Loading arms Platform meters
Cleaning-In-Place System for Fermenters, Centrifuges	Comprises 2 m^3 caustic tank and 2 off pumps

6. Piping and Valves

All pipework and valves, pipe supports, strainers, steam traps, flame arresters etc are included for the various plant sections.

7. **Electrics**

A motor control centre is included for all drivers together with all necessary starters, local on-off push-buttons, cabling and cable trays

8. **Instrumentation**

Instrumentation for the safe and efficient operation of the plant is included. The clarification section and yeast separation centrifuge will be controlled from a local control panel supplied with the centrifuges. A control room is provided for locating a control panel on which the main controllers for the distillation plant would be mounted. Important temperatures and flow rates throughout the plant would also be monitored from here.

9. **Civil engineering and buildings**

The establishment of a 107 000 ℓ/day ethanol distillery will require a site of dimensions 125 x 95 m. The civil engineering and building work associated with this will include the following main items:

1) Site clearance and levelling.

2) Preparation of foundations and bund walls when necessary for:

	(m)
Molasses storage	40 x 25
Product storage	50 x 40
Distillation plant	25 x 15
Cooling tower installation	12 x 10
Process water tank and pump	12 x 10

3) Buildings:

Clarification and fermentation	40 x 25 x 8 m high
Compressor house	10 x 10 x 3 m high
Laboratory/offices	8 x 8 x 3 m high
Control room/switchroom	12 x 8 x 3 m high
Chemicals store/workshop	16 x 10 x 3 m high

4) Tanker access:

Preparation of access to loading/unloading day for road tankers.

5) Drainage for entire site.

APPENDIX 6A
Annex 2

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OK Distillery Company Limited

Shell Company of the Islands Limited

Shell International Petroleum Company Limited

SPP Pumps Limited

Sulzer Bros (UK) Limited

Wanson Company Limited

Westfalia Separator A G

Worthington Simpson Limited

APPENDIX 6B

BY-PRODUCTS: FERMENTATION AND DISTILLATION PRODUCTS - OTHER PRODUCTS

CONTENTS

SUMMARY

1. Ethanol is presently produced at three distilleries. One, Beau Plan, started production in 1980. The others, at Médine and St Antoine are older. The principal product is potable alcohol. Markets for rum are examined in paras 5.10-21, Appendix 10, where it is concluded that the markets for potable alcohol are not likely to justify expanding its production. In this Appendix some modifications to the existing distilleries are suggested, in order to improve their performance. One man-month of technical assistance is also proposed, at a cost of Rs72 000 ($7 000).

2. Baker's yeast was produced in a plant at Beau Champ from 1975-78, but the factory was forced to close down, partly because of higher than estimated costs, but principally because of price cutting by its competitors in export markets.

3. Fodder yeast production from vinasse is also examined in Appendix 5. It is not likely to be a viable proposition.

4. Vinegar is produced at Médine for local consumption. It is not distilled into acetic acid.

5. Citric acid production should not be considered in Mauritius because the technology is advanced and world production and marketing are dominated and controlled by three or four producers.

6. Monosodium glutamate production capacity world wide is in excess of demand. Production for the domestic market only would not be viable.

7. Production of chemicals using ethanol as a feed stock is not viable, given the large scale of operation necessary, and the diminutive home market.

1. INTRODUCTION

1.01 Apart from its possible use as a fuel substitute the most important utilisation of ethanol in Mauritius is the production of potable alcohol which is sold as cane spirit or rum. Three distilleries on the island distil ethanol for this purpose. Their operation has been reviewed and suggestions are proposed for improvements to the plants which would increase their efficiency and lower their operating costs.

1.02 Ethanol may be used as an alternative to petroleum for the production of ethylene and acetaldehyde, from which most petrochemical industry products may be obtained. The feasibility of an ethanol-based chemical industry is examined.

1.03 Other products derived from the fermentation of molasses using appropriate yeast strains include bakers' yeast, fodder yeast, citric acid and monosodium glutamate. The possibilities for the production of these by-products of molasses have been investigated.

2. POTABLE AND OTHER ALCOHOLS

Current production

2.01 Ethanol is produced at three sugar factories in Mauritius - Medine, St Antoine and Beau Plan. Until recently there was also a distillery at Solitude, but this was closed when the new Beau Plan distillery started production in 1980.

2.02 Ethanol is primarily distilled for use as potable alcohol, but small quantities are also used for vinegar and perfume manufacture, and as denatured spirit for general industrial use. Production of alcohol in 1979 was 3.2 Mℓ 100°GL, from a molasses offtake of about 15 000 t (see para 3.02, Appendix 10).

Existing distilleries

2.03 The distillery at Medine was built in 1926 and produces about 600 000-700 000 ℓ of ethanol during the crop harvesting season and another 300 000 ℓ in the out-of-crop season. The latter volume is considerably more expensive to produce than the ethanol produced in the crop harvesting season; an oil fired boiler is used for steam generation when surplus steam from the sugar factory is not available. Two copper distillation columns produce rectified spirit at 94°GL. External coolers have recently been installed to the fermenting vessels in order to improve control of the fermenting temperature.

2.04 A small plant is associated with the Medine distillery in which ethanol is fermented to acetic acid which is diluted, bottled and sold as vinegar for local consumption.

2.05 St Antoine is the oldest distillery in Mauritius, built in 1900. Two distillation units produce 5 000 ℓ/d and 1 000 ℓ/d of ethanol respectively, both fed from the same fermentation plant.

2.06 A new distillery was commissioned at Beau Plan in 1980 which can produce 20 000 ℓ/d of ethanol. Four distillation columns provide facilities for the production of rectified spirit and extra neutral potable spirit. This distillery is owned by Harel Freres who bottle some of their own spirit at Solitude and in addition sell spirit to New Goodwill Limited and to Gilbeys. The design features incorporated in this plant include pasteurisation and sterilisation of molasses, external cooling of fermenting vessels, yeast centrifuging and recycling. Experiments are taking place to determine the most effective method of vinasse treatment in order to reduce the environmental impact of this waste product.

Production quotas

2.07 Potable alcohol is bottled and distributed by three companies, New Goodwill, Gilbeys and OK Distilleries (also owned by Harel Freres). Each year the distilleries agree quotas for potable spirit production so that each distillery provides approximately one third of the island's requirements. It is understood that currently the Beau Plan distillery is producing some of St Antoine's quota. It seems probable that the old, relatively inefficient distillery at St Antoine may eventually be closed especially as the other distilleries can easily supply the demand for potable alcohol.

Improvements to existing distilleries

2.08 A detailed study of the performance of the existing distilleries with specific recommendations for improving the yield of ethanol from molasses and reducing the operating costs is beyond the terms of reference of this study. However, it is suggested that the following modifications should be investigated with a view to improving the operation of the older distilleries. Some of these could be implemented with only minimal expenditure:

a) reduce evaporation losses during fermentation by fitting lids to the fermenting vessels;

b) instal external coolers for fermenting vessels in order to ensure fermentation at optimum temperatures;

c) change from using dried baker's yeast to brewer's yeast (Saccharomyces cerevisiae);

d) instal a preheater for the distillation feed utilising waste heat in the vinasse effluent stream;

e) instal a filter or centrifuge to remove solids from fermented wash which would increase the interval between shut-downs for cleaning distillation columns.

These are not included in project costs; they would be part of normal operating costs. One man-month of technical assistance to the distilleries has however been included at a cost of Rs72 000 ($7 000).

3. BAKER'S YEAST

3.01 Together with ethanol, baker's yeast is one of the earliest known products of the aerobic fermentation of sugar substrates. In a modern production plant, the molasses is continuously clarified and sterilised prior to fermentation. Fermentation is usually a batch process, and the yeast strain is propagated in a series of vessels of increasing size, before being placed in the main fermenters.

3.02 The fermenters are fitted with sparge pipes through which air is blown to provide the aerobic conditions for yeast growth rather than alcohol production. Nutrients are added to the fermenting liquor which is recirculated through coolers to maintain optimum temperature conditions. After fermentation the yeast is centrifuged and treated with salt, which removes water from the cell walls by osmosis. A portion of the yeast is used to seed successive fermentations, and the main product is filtered and dried.

3.03 A baker's yeast plant, employing the above process, was constructed at Beau Champ Sugar Estate in 1974 as a joint venture between Anchor Yeast of South Africa and Yeast Producers (Mauritius) Ltd. The South Africans provided the technical know-how for the plant, which was designed to produce 800 t/y of baker's yeast and cost Rs8 M ($1.3 M).

3.04 Because the market for baker's yeast in Mauritius is very small it was intended to develop export markets principally in Indonesia and Sri Lanka.

3.05 The plant was commissioned at the end of 1975 but was forced to close in 1978, the equipment being subsequently sold and shipped from Mauritius; a combination of technological and commercial factors caused the closure:

a) The international yeast market is highly competitive and dominated by a few large companies. In particular the French company Le Saffre was able to reduce the price of their baker's yeast sold to Indonesia. This forced the Mauritian company to sell yeast at below its production cost.

b) The keeping qualities of Mauritian baker's yeast were poor. This problem was aggravated when the dates of important shipments were delayed due to dock strikes at Port Louis, and buyers cancelled their contracts.

c) The tins produced locally for packing the yeast were of inferior quality. A shipment to Sri Lanka was ruined when the lids of the tins broke open during the voyage.

d) The production costs were higher than those of competitive brands, the high cost of electricity in Mauritius being an important element.

e) An export tax was raised on baker's yeast.

3.06 In the final year, a Canadian firm, Lallemand Inc, provided a chemist and as a result the company succeeded in manufacturing a first class yeast. However, the problems of costs and markets were not overcome.

The 1977 production costs of the baker's yeast plant are summarised below:

		Rs/kg yeast
Raw materials (including molasses @ Rs100/t)		1.79
Variable costs		
Steam	0.47	
Electricity	1.02	
Water	0.01	1.50
Fixed overheads		
Salaries and wages	0.60	
Medical/Insurance/Pensions	0.09	
Rents and sundry expenses	0.06	
Depreciation	0.56	
Maintenance - plant	0.09	
Maintenance - buildings	0.02	1.42
Interest on loans		0.71
Packing in 2.5 kg tins		1.35
Transport to Port Louis and dock dues		0.33
Total production costs:		7.10
	$	1.18/kg

3.07 The combination of a small local market and difficulties in establishing a long term export market suggest that further investment in baker's yeast production is unjustified.

4. FODDER YEAST

4.01 Fodder yeast is produced by aerobic fermentation, using a process similar to that for baker's yeast. A number of different varieties of yeast may be employed. Among the most suitable are Torulopsis utilis, Candida arborea and Candida utilis.

4.02 The molasses is clarified before fermentation and its pH reduced to between 3.5 and 4.5, depending on the yeast strain. It is important to ensure that the heat of reaction in the fermenters is removed by adequate cooling and that the fermenters are sufficiently aerated. After fermentation the yeast is separated in centrifuges and then washed and dried to a moisture content of about 8%. The yeast is then bagged as flakes or as a finely ground powder.

4.03 The composition of a typical yeast cake on a dry matter basis is:

	% w/w (DM basis)
Crude protein	54.5
Carbohydrate	34.5
Fat	3.8
Fibre	0.8
Ash	6.4
CaO	0.5
P_2O_5	1.9

4.04 Production costs, feed values and markets are covered in paras 2.32-2.34, Appendix 5 in which it is concluded that the production of fodder yeast is unlikely to be a viable proposition.

5. VINEGAR/ACETIC ACID

5.01 Vinegar is manufactured at Médine Distillery from its production of 94°GL ethanol. The ethanol is diluted to 10°GL and nutrients added prior to fermentation in wooden vessels. The vinegar produced contains 70 g of acetic acid/ℓ of liquor. This is diluted to 35 g/ℓ and sold in plastic litre bottles. About 100 000 ℓ/y of vinegar is produced at Médine. Pure acetic acid is not redistilled from the vinegar.

5.02 Vinegar production at Médine is essentially a very small scale operation and there appears to be litt : possibility for expansion because of the limited local m. .et.

6. CITRIC ACID

6.01 Citric acid is obtained from the fermentation of molasses using strains of the fungus <u>Aspergillus niger</u>. The molasses must be pretreated by clarification, sterilisation and dilution to a sugar concentration of approximately 15%. The precise fermentation conditions of temperature, pH and nutrient dosages depend upon the particular strain of fungus used. Phosphate and nitrogen nutrients are essential and the fermentation time is typically 8-12 days. The fermented product is purified by precipitation, acid treatment, evaporation, crystallisation and drying.

6.02 World production and marketing of citric acid is an oligopoly being dominated by three or four major producers who have developed improved strains of A. niger for obtaining high yields. These strains are very sensitive to their environmental conditions, so that considerable knowledge and skill are needed to design and operate a citric acid plant. The strains are only available from the major citric acid manufacturers who do not release cultures for new companies to start production and encroach upon their markets. Without the collaboration of these companies, and in view of the small local market citric acid production in Mauritius is not seen as a viable proposition.

7. MONOSODIUM GLUTAMATE (MSG)

7.01 Monosodium glutamate (MSG) is used to intensify the flavour of food. It is manufactured by the anaerobic fermentation of molasses by strains of Micrococcus glutamicus under slightly alkaline conditions in the presence of urea. Purification of the product is a complex process requiring several stages of evaporation crystallisation and filtration.

7.02 In global terms considerable excess production capacity exists for MSG, the Far East being the major producing region. In view of this, it is difficult for any new producer to enter the world market. With the limited domestic market opportunities, it would not be appropriate to invest in plant to produce this by-product in Mauritius.

8. ETHYLENE AND ITS DERIVATIVES

Derived chemicals and polymers

8.01 Ethanol may be converted to ethylene and acetaldehyde from which the majority of chemicals, polymers and plastics normally produced by the petrochemical industry may be derived. Details are shown below of important products for which ethylene and acetaldehyde are the feedstocks.

Feedstock	Chemical derivatives	Polymer derivatives
Ethylene		Low density polyethylene (LDPE)
		High density polyethylene (HDPE)
	Vinyl chloride	Polyvinyl chloride (PVC)
	Ethyl benzene	
	Styrene	Polystyrene
Acetaldehyde	Vinyl acetate	Polyvinyl acetate (PVA)
	Butadiene	Nylon
	Acetic anhydride	
	Ethyl acetate	

Ethylene and acetaldehyde production

8.02 Ethylene can be manufactured from ethanol by dehydration in the presence of an acid catalyst at high temperature. Usually sulphuric acid or phosphoric acid is employed and the reaction temperatures may be as high as 200°C. An alternative catalyst is alumina which requires a temperature of 350-400°C. In Brazil, research and development work is being undertaken utilising a silica-alumina catalyst.

8.03 Acetaldehyde may be produced from ethanol by catalytic dehydrogenation. The catalyst has a copper/chromium base over which ethanol vapours are passed at 300°C and low pressure. About 90% of the ethanol is converted to acetaldehyde. By-products formed by the remaining 10% ethanol include ethyl acetate, acetic acid, methyl-ethyl-ketone and butanol.

8.04 The various chemical and polymer derivatives of ethylene and acetaldehyde may be obtained using well established petrochemical processes.

Economic plant capacity

8.05 Ethlylene plants using petroleum fractions as their feed material benefit from economies in scale of production. The largest petrochemical units currently under construction will produce 500 000 to 600 000 t/y of ethylene. Ethylene plants using ethanol as feed have been built in Brazil and have a capcity of 10 000 to 60 000 t/y. The extensive land area required to grow the sugar for conversion to ethanol is the limiting factor in determining ethylene plant capacity.

8.06 The following data illustrate the quantities of ethanol and molasses required for typical ethylene and acetaldehyde plants to be economic.

Plant	Minimum economic capacity t/y	Ethanol Mℓ/y	Molasses t/y
Ethylene	25 000	54.1	215 000
Acetaldehyde	12 000	17.5	70 000

In Mauritius the joint requirements of molasses for production of ethanol for motor fuel and for ethylene feedstock - together with other purposes - exceed the predicted supply of 199 000 t in 1990. Alternative sugar substrates such as sugarcane juice would have to be considered to supplement molasses.

Market potential

8.07 The import statistics do not record the tonnages of individual petrochemicals and plastics. As can be seen from the data below, however, the total imports of petrochemical products are less than 4 500 t/y which is too low for any consideration to be given to the establishment of production facilities in Mauritius for the domestic market.

Products	Imports, 1980 t
Products of condensation, polycondensation and polyaddition:	
a) In liquid or paste form, blocks, lumps, powders, granules and flakes	607.5
b) In other forms	147.7
Products of polymerisation and copolymerisation:	
a) In liquid or paste form, blocks, lumps, powders, granules and flakes	1 235.1
b) In other forms	1 774.5
Other organic chemicals except acids, aldehydes and alcohols (1977 data)	550.7
Total	4 315.5

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

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Institutions

ACP	Lomé Convention countries of Africa, the Caribbean and the Pacific
A&M	Alcohol and Molasses Export Company Limited
ADB	African Development Bank
AMB	Agricultural Marketing Board
CCCE	Caisse Centrale pour la Cooperation Economique (Paris)
CEB	The Central Electricity Board
CSA	Commonwealth Sugar Agreement
DBM	Development Bank of Mauritius
FAO	Food and Agriculture Organisation of the United Nations
IBRD	International Bank for Reconstruction and Development (World Bank)
IDA	International Development Association (World Bank)
ISO	International Sugar Organisation
MCAF	Mauritius Cooperative Agricultural Federation Limited
MCCB	Mauritius Cooperative Central Bank Limited
MCGA	Mauritius Cane Growers Association
MM	Mauritius Molasses Limited
MMA	Mauritius Meat Authority
MMPA	Mauritius Meat Producers Association
MRC	Mauritius Research Council
MSCPA	Mauritius Sugar Cane Planters Association
MSS	The Mauritius Sugar Syndicate
MSPA	Mauritius Sugar Producers Association
MSIRI	Mauritius Sugar Industry Research Institute
ODA	Overseas Development Administration (London)
PROSI	Public Relations Office of the Sugar Industry
U of M	University of Mauritius
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organisation
UNCDF	United Nations Capital Development Fund

<u>Units and Technical Abbreviations</u>

bar A	measure of absolute pressure (1 bar A is effectively 1 atmosphere)
brix	weight of solids % weight of solution
BOD	biological oxygen demand
¢	cent
C	Centigrade
cif	cost, insurance and freight
COD	chemical oxygen demand
CP	crude protein
cumec	cubic metre/second
d	day
DM	dry matter
fcf	fresh, chilled and frozen
fob	free on board
gal	Imperial gallon
GL	Gay Lussac (100°GL is 100% alcohol)
GWh	Gigawatt-hour
GNP	Gross national product
g	gram
ha	hectare
hr	hour
IRR	Internal Rate of Return
kg	kilogram
kJ	kilojoule
km	kilometre
kWh	kilowatt-hour
ℓ	litre
lb	pound
m	metre
m^2	square metre
m^3	cubic metre
M	Million
ME	Metabolisable energy
MJ	megajoule
MSG	Monosodium glutamate
MW	megawatt
NCV	net calorific value
NFE	Nitrogen free extract
NPV	Net present value
Rs	Mauritius Rupees
t	tonne
tc/d	tonnes cane per day
tc/hr	tonnes cane per hour
t/ha	tonnes per hectare
y	year

MAURITIUS SUGARCANE BY-PRODUCTS STUDY

NOTES ON EXCHANGE CONVERSIONS AND LOCAL UNITS

Exchange conversions

Costs are based on those at 1 July 1981. Exchange rates are those after the devaluation in October 1981

ie US$1 = Rs10.25
£1 = Rs19.00

The devaluation during report writing has made cost estimation particularly difficult. The foreign exchange components have been converted at the new rates. However, it is not possible to make accurate new estimates of all local costs, given that the devaluation would eventually affect some, but not all. For example, the cost of steam in the sugar factories would probably not be affected, but that of electricity would increase to the extent that imported fuel is used to generate it.

Conversion rates in the other Appendices are historical,

ie	October 1979 - October 1981	US$1 = Rs8.67
	January 1977 - September 1979	US$1 = Rs6
	Sugar crop season 1979/80 (average)	US$1 = Rs7.335

Costs before 1977 have not been converted to dollars. The figures for Universal Board Company Limited in Appendix 8 are based on historical costs (and not converted to dollars) or on operating costs prepared by the liquidators and based on the July 1981 rate of US$1 = Rs8.67.

(Appendix 11)

Local units

1 arpent	=	1.043 acres = 0.422 ha
1 foot	=	0.3048 metres
1 pound (lb)	=	0.4536 kg
1 gallon	=	4.546 ℓ

APPENDIX 7A

BY-PRODUCTS: ENERGY FROM BAGASSE - ELECTRICITY

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ANNEXES

SUMMARY

1. The average sugar milling season lasts 134 days, and the 21 factories crush 6 217 000 t cane. They produce bagasse in excess of their own energy requirements, and some of this is used to generate electricity for sale to The Central Electricity Board (CEB). Sales in 1980 were 27 GWh.

2. The boilers in the majority of the sugar factories produce steam at 21 bar A at 350°C. Boilers at Medine produce steam at 31 bar A at 400°C, and similar ones have been installed elsewhere. This live steam is used to drive the prime movers of the factories, and to generate electricity. Typical power station conditions are 71 bar A at 500°C.

3. The process section requires steam at 2 bar A; back pressure turbines are used to generate electricity and produce exhaust steam at that pressure. Condensing turbines produce exhaust steam at a near-vacuum, typically 0.10 bar A in a sugar factory and 0.05 bar A at a power station. Back pressure turbines are cheaper and simpler to operate than condensing turbines, but the latter generate more power. By increasing the efficiency of the process section in terms of demand for steam, more bagasse can be made available to fuel a condensing turbine.

4. The sugar factories in Mauritius are categorised into three groups according to energy balances:

Group I: Six small factories (total capacity 460 tc/hr) with little scope for development of energy production.

Group II: Six medium factories (total capacity 680 tc/hr) with simple process sections.

Group III: Nine larger factories (total capacity 1 210 tc/hr) with rather more economical process sections in terms of steam.

5. Three further categories are defined:

Group IV: Group II and III factories with their process departments optimised.

Group V: Group II and III factories equipped with higher pressure boilers (31 bar A at 400°C), and with efficient turbo-alternators.

Group VI: Factories equipped with boilers at 46 bar A at 440°C. This represents the ultimate efficiency attainable in a sugar factory.

6. CEB controls the supply and distribution of electricity, which comes from three sources:

	Production GWh
Hydro-electric	100
Diesel	270
Purchases (mainly from sugar estates)	48

7. The above production figures include equipment currently being installed. CEB is considering building a 30 MW coal-fired power station at Port Louis operating at 71 bar A at 500°C and producing 170 GWh/y. Present annual demand is 355 GWh; sales are projected by CEB to rise at 4%/y to the end of the century.

8. The daily demand curve is made up of three separate loads:

- the base load, averaging 25 MW;
- the day load, a further 25 MW; and
- two peak periods, an extra 33 MW at the maximum.

9. Back pressure turbines are ideal for producing electricity for the base load. Condensing turbines are effective for the day load, using bagasse stored during the night. Ideally, peaks are supplied by hydroelectric power, with its ease of starting up; unfortunately, water may not always be available, and the make-up is then with diesel generators. Presently these generators provide the majority of all three loads, although purchases account for about 40% of the base load during the sugar crop season.

10. Electricity production by the sugar factories during the crop only means that CEB must have at its disposal sufficient equipment to meet demand out of crop. Therefore the only saving to CEB from the present purchases is the cost of the fuel which would otherwise be needed. Clearly the development of year-round production of electricity from bagasse would have much greater value.

11. Large-scale storage and transport of bagasse are both difficult and expensive. Past methods of storing bagasse in dry forms have not been satisfactory. However, a method of making pellets from wood chips has recently been adapted to bagasse. This is the Woodex process; a plant is currently in its first full season of production at a factory in Hawaii, with encouraging results. The cost of that plant was Rs29 M ($2.83 M) and its expected output in Hawaii is 20 000 t/y pellets. Its operating costs are not yet known. It will be necessary to evaluate the process further before any decision can be made on its use. A pilot plant is included in project costs at Rs29 M ($2.83 M).

12. Presently the electricity exportable to the grid is 47.8 GWh/y including the 10 MW condensing turbo-alternator installed in 1981 at Medine; the surplus bagasse is 186 000 t/y. On the assumption that bagasse may be stored between crops, electricity production may be maximised as follows:

Step I: Upgrade all Group II and III factories to Group IV. This would produce 9.7 GWh/y from back pressure turbo-alternators, surplus bagasse of 344 000 t/y, and would cost Rs11.43 M ($1.12 M).

Step II: Instal Woodex pelleting equipment at all Group IV factories, giving 277 000 t pellets/y, at a cost of Rs307 M ($30 M).

Step III:

Option A CEB instals its 30 MW coal fired power station at Port Louis, equipped to burn bagasse pellets. Total electricity produced from bagasse would be 229 GWh/y, providing an average of 30 MW during its 320 day operating year. The capital cost would be Rs350 M ($34.1 M).

Option B: Instal 3 10 MW regional power stations in existing factories; these would operate as Group VI factories. The total electricity produced from bagasse would be 201 GWh/y, at an average of 26 MW. The capital cost would be Rs240 M ($23.4 M), including boilers.

Option C: Use the existing 31 bar A boilers, and the condensing turbo-alternator at Medine, thus limiting purchases to two turbo-alternators at other factories. Total energy produced from bagasse would be 182 GWh/y, at an average of 24 MW. The capital cost would be Rs80 M ($7.8 M).

Summary costs are as follows:

	--------Capital---------			Operating (2nd and subsequent years) 1/	
	(para)	Rs M	$ M	Rs M	$ M
Step 1	(8.08)	11.43	1.1	0.33	0.032
Step 2	(8.10)	307	30	23	2
Step 3 Option A	(8.12)	350	34.1	12	1
Option B	(8.15)	240	23.3	8	0.8
Option C	(8.20)	80	7.7	3	0.3
Total costs:					
Option A		668	65.2	35	3.3
Option B		558	54.4	25	2.5
Option C		398	38.8	21	2.0

1/ Excluding depreciation and interest.

13. Costs of production under the three options, compared with coal fired electricity, are as follows:

	Rs/kWh	US¢/kWh
Option A	0.560	5.4
B	0.516	5.0
C	0.420	4.0
Coal-fired	0.688	6.8

These costs include depreciation and interest.

14. If all Group II and III factories were developed to Group VI, and Option A adopted, electrical energy produced would total 429 GWh/y, at an average of 56 MW. However, this would entail massive investment in the sugar industry; the figures are presented merely as theoretical maxima.

15. The alternative of maximising production during the crop season only is discussed. It has not been costed, firstly because it is comparatively so unattractive, and secondly because detailed information would be required from each factory. Step 1 is unchanged, the improvement of the process departments of Group II and III factories to Group IV. Step 2 (crop season) would involve the development of the 5 factories fitted with 31 bar A boilers into Group V factories. Total electricity produced from bagasse would be 166 GWh/y. This would supply the base and day loads during crop until 1990.

16. If all sugar factories were converted to Group VI (the theoretical and probably unattainable peak), production of electricity during the crop only would reach 338 GWh/y.

17. Under Option A, annual production of electricity from bagasse on a year round basis may be expected to rise from 27 GWh/y in 1980 to 229 GWh/y, with a theoretical maximum of 429 GWh/y. Expected electrical demand in the year 2000 is 778 GWh/y. There will then be a shortfall of 349-549 GWh/y, which would be partly met by existing sources (hydroelectricity of 100 GWh/y and diesel

generators of 270 GWh/y), but which could require investment by CEB in a coal fired power station in the forseeable future, particularly given the likely phasing out of the diesel equipment.

18. Financial analysis of the options shows that the returns on capital, expressed in the form of internal rates of return, are:

	IRR %
Coal fired central power station	19.8
Option A	21.3
Option B	22.6
Option C	26.4

The net present value of Option [illegible] is bigger than those of the other options at interest rates down to 10%.

The calculations assume a nil cost for bagasse.

If the net cash movements of Options A and B are compared with the coal fired power station, the returns on the investments in the process sections and in the pelletisation plants are:

	IRR %
Option A/coal	23.6
Option B/coal	34.4

19. Option C produces 79% of the energy of Option A, at 75% of the capital cost. A sub-option currently under investigation by the WEAL group, the installation of a 20 MW set at F.U.E.L. operating at 46 bar A, would give 86% of the energy of Option A. Option C presents the most attractive method of generating electricity from bagasse, given that much of the investment has already been made by the sugar companies. An unquantified benefit is the electricity generated during the crop while bagasse pelleting is being developed.

20. Investigations to be carried out are listed. The critical one is that of pelletisation of bagasse, and the method of study is indicated. Its cost is estimated at Rs646 000 M ($63 000) for 10 man-months. Other investigations are currently being carried out by French consultants, Trans Energ, and by the WEAL group.

21. A Central Energy Planning Committee is proposed, responsible to the authority at ministerial level to be established to develop national exploitation of sugarcane by-products. Its principal functions would be planning and coordination.

1. INTRODUCTION

1.01 Bagasse has traditionally been used for generation of the steam and power required to operate sugar factories. Given the present high energy prices, factories will continue to depend for the forseeable future upon bagasse for their energy requirements. However, recent improvements in the technologies involved now make it feasible to meet the factory's energy requirements using only a part of the total bagasse, the surplus bagasse thereby becoming available for alternative uses. In this Appendix the technological changes and investments needed to provide surplus bagasse in significant quantities are examined. The potential for production and sale of electricity generated from bagasse are then considered from both technical and financial viewpoints. On account of the very wide ranging issues raised by the analysis (and the interrelations between the plans of the sugar industry and of The Central Electricity Board (CEB)) the conclusions given can only be of a preliminary nature. In Appendix 7B we examine alternative methods of commercialising energy from bagasse; namely production of charcoal, biogas and producer gas.

2. THE SUGARCANE PROCESSING INDUSTRY

Factory processes

2.01 The composition of the cane sent to the factory varies according to variety, season, locality, age etc, but as a general rule, its constituents have the following proportions:

Solid fraction known as fibre:		11-16% cane
Liquid fraction known as absolute juice:		84-89% cane
Composition of absolute juice:	Brix 1/:	15-20°
	Water:	80-85%
	Purity 2/:	80-90

2.02 The factory process may be broadly divided into the following sections.

1/ Brix: weight of solids % weight of solution.
2/ Purity: weight of sucrose % brix.

Preparation

2.03 Cane is first weighed and then prepared for milling by passing it through cane cutters and a shredder composed of revolving knives and hammers which break open some 80% of the tissue cells without extracting the juice.

Extraction

2.04 Juice is extracted by crushing the prepared cane through a mill tandem composed of five or six three-roller mills leaving behind a fibrous residue known as bagasse. Simultaneously water (described by the industry as 'imbibition' water) is added to the bagasse matt before the last mill and the juice extracted by that mill is recirculated to the bagasse entering the previous mill and so on, so as to obtain a counter-current washing of the bagasse as it moves along the mill tandem, thus improving the extraction of sucrose from the cane.

2.05 In some cases the mill tandem, or part of it, is replaced by a diffuser in which the bagasse bed is washed instead of being crushed in order to extract the sucrose. However, a dewatering mill must be placed after the diffuser in order to dry the bagasse to a level acceptable to the boilers.

2.06 Generally the amount of "mixed juice" extracted by a mill tandem is approximately equal to 100% of the weight of cane crushed (cane plus imbition water equals mixed juice plus bagasse: if cane equals mixed juice then imbibition water is equal to the weight of bagasse leaving the last mill).

2.07 With a diffusion plant, the weight of mixed juice obtained is typically 110% of the weight of cane treated.

2.08 Some interesting points may be noted:

a) the weight of fibre entering and leaving the extraction plant remains constant, and the throughput of a mill or diffuser depends solely on the amount of fibre passing through it and not on the amount of cane;

b) bagasse has a relatively constant composition throughout the crop; it is approximately as follows:

Fibre %	=	48.00
Brix %	=	2.00
Moisture %	=	50.00
Net calorific value (NCV)	=	7 641 kJ/kg; and

c) mixed juice has approximately the following composition:

Brix	=	13-15°
Purity	=	85

Clarification

2.09 After screening, the mixed juice is sent to the clarification section where it is limed to a neutral pH and heated to 105°C, thus precipitating colouring matter, organic acids, albuminoids and miscellaneous suspended matter. The limed juice is then allowed to settle in the clarifier where the precipitates move to the bottom and are extracted as mud, while the clear juice goes to the evaporators.

2.10 In order to minimise sugar losses, the mud is filtered and washed before being discarded from the factory.

Evaporation

2.11 In this section, clarified juice which has approximately the same concentration as mixed juice is evaporated in a multiple effect evaporator to a syrup of 60° brix.

Boiling and centrifuging

2.12 Syrup is evaporated under vacuum to such a concentration that sugar crystals form out of the solution. This mixture of crystals and molasses is known as A-massecuite. It is centrifuged in a basket lined with a screen which allows the A-molasses to pass through it, while retaining the A-sugar. The A-molasses is further boiled into a B-massecuite from which B-molasses and B-sugar are similarly separated. The B-molasses is boiled into a C-massecuite from which C-molasses and C-sugar are obtained. C-molasses is discarded from the factory as it is uneconomic to recover any further sugar. A and B-sugars are exported as commercial raw sugar. Their purity is of the order of 99. C-sugar has a purity of 85 and is remelted and sent back for crystallisation.

Steam production and utilisation

2.14 Bagasse is burned in boilers equipped with specially designed furnaces (these furnaces may be used to burn wood at start-up, but are unsuitable for coal) in order to produce steam for factory requirements. These requirements are:

a) live steam (ie high pressure steam) for the prime movers ie cane cutters, shredder and mill drives, turbo-alternator and any other drives used in the factory. These machines utilise live steam from the boilers and exhaust it at 2 bar A 1/ for the process; and

b) exhaust steam at 2 bar A is used by the evaporator, juice heaters, vacuum pans and for miscellaneous small demands.

In a well designed factory, the energy content of the bagasse is higher than the energy needs of the factory, hence the possibility of producing electricity and exporting it to the national grid. Key objectives of this report are the determination of the amount of electrical energy that could be produced from the factories under present conditions, and the means of increasing this in the future.

Performance

2.15 Factories operate round the clock except for Sundays and public holidays. Excluding abnormal years (1971, 1975, 1980), the average weight of cane crushed annually amounts to 6 217 000 t and the total number of crushing days averaged 134. End Table 1 gives the performance figures of the sugar industry of Mauritius for the period 1971-80, and Appendix 1 describes the industry in greater detail.

2.16 Considering Mauritius as a whole, the following figures have been assumed to represent a 'standard crop', ie excluding the abnormal years:

Weight of cane crushed annually		:	6 217 000 t
Fibre % cane		:	13.50
Duration of crop harvesting		:	134 days
Crushing time		:	19.85 h/d
		:	2 660 h/y
Total industry crushing rate		:	2 350 tc/hr
Composition of bagasse:	fibre %	:	48.00
	moisture %	:	50.00
	brix %	:	2.00
	NCV	:	7 641 kJ/kg
Mixed or clarified juice % cane		:	100.00
Brix of clarified juice		:	13.50°
Brix of syrup		:	61.00°

2.17 There are 21 factories in operation and End Table 2 indicates their crushing rates for the period 1971-80. End Table 3 gives an outline of the steam generating equipment installed, and the type of process used in each factory. End Table 4 gives the amount of electrical energy exported by the sugar factories to the national grid for the period 1975-80.

1/ Effectively twice atmospheric pressure.

3. POWER GENERATION IN THE FACTORY

Steam turbines

3.01 In order to appreciate the following discussion, it may be helpful to recapitulate the fundamental principles of steam turbines.

3.02 In a turbine, the energy of the live steam is transformed into kinetic energy by expanding it through a bank of nozzles. The stream of high velocity particles is directed tangentially towards the blades of the rotor upon which they impinge, producing a torque, thus transforming part of the energy contained in the steam into shaft energy. Expansion can take place in one or several stages depending on the design of the turbine.

3.03 Not all the energy content of the steam can be transformed into kinetic energy. The maximum amount that can be transformed depends solely on the inlet and outlet conditions of the steam, and is called the isentropic heat drop. The fraction of the isentropic heat drop that is actually transformed into shaft energy is called the internal efficiency of the turbine. It is of the order of 55-65% for single stage turbines, and 75-80% for multi-stage designs. All the internal losses appear as heat in the exhaust steam.

3.04 The other losses which must be taken into consideration in the case of a turbo-alternator installation are:

a) mechanical losses at the bearings and gear box and electrical losses at the alternator and transformer. These add up to 5% of the energy at the turbine shaft (a figure of the same order applies to the gear train of a mill drive); and

b) energy consumed by the auxilaries of the boiler and turbine. This loss is estimated at 0.4% of the heat input in the fuel in case of a back pressure set, and 2.0% in case of a condensing turbine.

3.05 A turbine exhausting steam at a pressure higher than atmospheric is called a back pressure turbine. A sugar factory needs 2 bar A steam for its process, therefore live steam from the boiler is passed through a back pressure turbine exhausting at 2 bar A before going to the process, thus producing shaft energy at the turbine.

3.06 When there is no demand for exhaust steam, the shaft energy output of the turbine should be maximised. In order to do so the exhaust pressure should be reduced to a minimum. The lowest possible pressure (ie a vacuum) is achieved by condensing the exhaust steam in a surface condenser adjacent to the turbine, hence the name condensing turbine. In power stations, condensing turbines are universally used.

3.07 In certain cases a combination of these two types of turbine is used. It is the pass-out/condensing turbine. It consists of a condensing turbine divided into two sections: the high pressure (HP) section which is identical to a back pressure turbine, and the low pressure (LP) section which is a condensing turbine in which the inlet steam is the exhaust from the HP section. Steam coming out of the HP section can either go through the LP section or be diverted to the process (however, a small amount of steam should always pass through the LP section in order to cool the machine and maintain the vacuum). This flexibility can be very convenient under certain conditions, as will be seen later.

3.08 In order to illustrate the energy distribution of a turbine installation, 10 different cases have been presented in End Table 5, representing typical conditions encountered in sugar factories and power stations (calculations are given in Annex 1). In developing these 10 cases the following typical conditions were assumed:

a) Live steam:

i) steam at 21 bar A at 350°C which is representative of the majority of sugar factories operating in Mauritius;

ii) steam at 31 bar A at 400°C which is typical of the recently installed boilers (in all but one of them, the working pressure has been limited to 21 bar A because the existing prime movers have not yet been replaced);

iii) steam at 46 bar A at 440°C representing the highest pressures that can be envisaged under normal sugar factory conditions; and

iv) steam at 71 bar A at 500°C, which is typical of power station conditions.

b) Exhaust steam pressures:

i) 2 bar A which is the standard pressure used in the sugar factory process section;

ii) 0.10 bar A which is the vacuum obtainable in a sugar factory where condenser water is put through a cooling tower; and

iii) 0.05 bar A which is the vacuum obtainable when sea water is utilised for the condenser, as would be the case for a coal fired power station in Mauritius.

c) Types of turbines:

i) single stage back pressure turbines with an internal efficiency of 0.55. These turbines are normally utilised for mill drives because of their simplicity and low capital cost;

ii) multistage back pressure turbines with an internal efficiency of 0.80. These turbines are utilised for turbo-alternators in the sugar industry because of their low steam consumption; and

iii) multistage condensing turbines with an internal efficiency of 0.80. These turbines are used mainly in power stations.

d) Boiler effiencies These have been taken as 0.84 based on the net calorific value of the fuel, in all cases.

Comparison of back pressure and condensing turbines

3.09 Using the data provided in End Table 5 a comparison between these two types of machine is derived:

a) In a back pressure installation, for a net energy input of 100 units in the fuel, 16 are lost in the flue gases and the difference is shared between shaft energy and process energy. This means that for a given process energy demand, the amount of shaft energy obtainable is limited by this ratio, which is governed solely by the inlet and outlet steam conditions and by the internal efficiency of the turbine. It must be emphasised that the transformation of energy of a back pressure turbine is 100%, ie energy in inlet steam minus energy going to process is equal to energy output of the turbine. With a boiler efficiency of 0.84 and a turbo alternator electrical efficiency of 0.95, if 100 units of energy are added in the fuel to raise the steam conditions from process conditions to live steam conditions, then 0.84 x 0.95 x 100 ie 80% of this energy is transformed into electrical energy. Therefore wherever there is a process steam demand, a back pressure turbine should be installed to obtain maximum benefit from this high energy transformation.

b) In condensing turbines, the circumstances are different. Heat going out in the exhaust steam is considered as lost; hence the energy transformation of these machines is low. In the best instance this efficiency is less than 27%. However, when there is no process steam demand, the electrical/mechanical energy output of the turbine becomes the governing factor in the choice of a machine, and in absolute terms the condensing machine develops much more power than the back pressure one. For this reason, by decreasing the process demand of a sugar factory, and utilising the surplus bagasse obtained to operate a condensing turbo-alternator, the total electrical output of the factory is increased.

c) The utilisation of back pressure turbines is restricted to the time during which the process is in operation and requires exhaust steam. In the case of a sugar factory, the average number of operating days per year is 134, and the number of operating hours per day is of the order of 20. This means that CEB will never be able to rely on the back pressure energy from the sugar estates to replace its installed equipment even during the crop.

d) Condensing turbines are much more complex and expensive than back pressure ones which are compact and simple to operate. The energy consumed by their auxiliaries is also much higher.

4. ENERGY BALANCE IN A 100 tc/hr FACTORY

4.01 The energy demand and production of a factory crushing 100 t of "standard" cane (para 2.16) per hour are detailed below.

Energy demand

4.02 Power requirements of prime movers

Cane-cutters (each)	:	7.5 kW/t fibre/hr
Shredder	:	15.0 kW/t fibre/hr
Mills (each)	:	15.0 kW/t fibre/hr

A factory equipped with two cane-cutters, one shredder and six mills requires 120 kW/t fibre/hr. Hence a factory processing 100 tc/hr at 13.5% fibre content requires 1 620 kW for its cane preparation and milling sections. The turbines used for this purpose are usually of the single stage back pressure type, with internal efficiencies of the order of 0.55. Multistage back pressure machines are seldom used because of their higher capital cost.

4.02 Electrical energy demand Experience has proved that a 1 200 kW turbo-alternator is adequate for the electrical load of a 100 tc/hr factory. In this case the turbines are usually multistage back pressure machines with internal efficiencies of the order of 0.80.

4.03 Process steam demand In most cases steam used for this purpose is saturated steam at 2 bar A. Since the condensates are returned to the boiler, the heat given to the process is equal to the latent heat of steam at 2 bar A ie 2 202 kJ/kg. Three levels of process thermal efficiency may be defined:

Level 1:

In a well designed factory using:

i) quintuple effect evaporation;

ii) vapour I for massecuite boiling; and

iii) vapour IV, III, II and I for juice heating;

the process steam demand is equal to 36.6% of the weight of cane crushed (see Annex 2) corresponding to a heat demand of 80.573 x 10^6 kJ/100 tc.

Level 2:

In a factory utilising:

i) quadruple effect evaporation;

ii) vapour I for massecuite boiling; and

iii) vapour II and I for juice heating;

the process steam demand is equal to 41.6% of the weight of cane crushed (see Annex 3) corresponding to 91.647×10^6 kJ/100 t of cane.

Level 3:

In a less efficient factory utilising:

i) quadruple effect evaporation;

ii) exhaust steam for massecuite boiling; and

iii) vapour I for juice heating;

the process steam demand is equal to 47.6% of the weight of cane crushed (see Annex 4) corresponding to 104.890×10^6 kJ/100 t of cane.

4.04 Miscellaneous demands This item comprises:

Small demands like:
Steam injection in centrifugals
Steaming of vacuum pans
Steam ejectors
Heating of molasses etc

Losses such as:
Condensation in pipes
Leaks
Blow downs
Thermal losses etc.

This item is estimated at 6.0 t/hr of live steam. Since the condensates are not recuperated, the heat lost is equal to the energy required to raise 6.0 t of water from 25°C to live steam conditions:

a) for live steam at 21 bar A at 350°C this loss amounts to 18.192×10^6 kJ/hr (see Annex 5);

b) for steam at 31 bar A at 400°C this loss amounts to 18.756×10^6 kJ/hr; and

c) for steam at 46 bar A at 440°C this loss amounts to 19.170×10^6 kJ/hr.

Energy production

4.05 Availability of bagasse:

Fibre content of cane	:	13.5%
Fibre content of bagasse	:	48.0%
Net calorific value of bagasse	:	7 641 kJ/kg

Weight of bagasse/100 tc/hr $= \frac{13.5}{48.0} \times 100 = 28.125$ t/hr

A loss factor of utilisation of the bagasse must be employed. This factor takes into consideration bagasse which is used for warming up the boilers from cold, bagasse burned during break-downs and various other losses. Under Mauritian conditions, a factor of 0.9 seems reasonable. The weight of bagasse utilised during actual crushing time is therefore: 28.125 x 0.9 = 25.313 t/hr.

4.06 Efficiency of boilers Formerly when a surplus of bagasse was expensive to dispose of, boilers were often designed with low efficiencies so as to burn the total bagasse produced. However, conditions are changing and modern boilers, equipped with economisers and/or air heaters, have efficiencies of the order of 0.84 or more based on the NCV of bagasse. (The older designs had efficiencies of 0.75-0.80 on the NCV of bagasse.)

4.07 Steam conditions Steam conditions encountered in the Mauritian sugar factories are:

a) less than 11 bar A for the fire-tube boilers encountered mainly in the smaller factories (see End Table 3);

b) 21 bar A at 350°C for the first generation of water-tube boilers;

c) 31 bar A at 400°C for the second generation of water-tube boilers, mostly installed in the mid-1970's;

d) 46 bar A at 440°C for future projects.

Higher steaming conditions are feasible but so far the following drawbacks have prevented their adoption:

- equipment becomes costly and sophisticated;
- feed water treatment is critical; and
- it is necessary to employ specially trained personnel.

4.08 Bagasse utilisation In normal practice just enough steam is generated to fulfil the requirements of the factory. This means that a surplus of bagasse is obtained. Alternatively, all the bagasse can be burned (provided the boilers are over-sized for the factory), in which case there is an excess of steam available. This excess of steam can be utilised in a condensing turbo-alternator to produce energy for the national electricity grid. The amount of electrical energy obtainable from bagasse under various operating conditions is given in End Table 6.

5. CLASSIFICATION OF THE MAURITIUS FACTORIES ACCORDING TO ENERGY BALANCE

5.01 Each factory has a different energy balance depending on the steam and power equipment available and the type of process utilised. In order to simplify the analysis, the factories have been classified into six groups having the characteristics outlined below.

5.02 Group I Representative of the older type of factories in Mauritius. The main features of this group are:

a) boiler: steam conditions - less than 11 bar A with various degrees of superheat;

b) turbo-alternator: single stage back pressure type with internal efficiency of turbine equal to 0.55;

c) prime movers: single stage back pressure turbines with internal efficiencies equal to 0.55; and

d) process: evaporation - quadruple effect utilising 2 bar A exhaust steam; massecuite boiling - vapour I/exhaust steam utilised; juice heating - vapour I and exhaust steam utilised.

These factories are the smallest production units and appear near the bottom of End Table 3; they represent a total crushing capacity of some 460 tc/hr only. There is not much scope for developing the energy production of these factories because of their size and of the limited possibilities of their boiler plant. Therefore this group of factories has not been taken into consideration in the estimates of increased power generation.

5.03 Group II The main features of this group of factores are:

a) boiler: steam conditions - 21 bar A at 330°C: efficiency based on NCV of bagasse 0.78;

b) turbo-alternator: multistage back pressure turbine with internal efficiency equal to 0.80;

c) prime movers: single stage back pressure turbines with internal efficiency of 0.55; and

d) process: evaporation - quadruple effect utilising 2 bar A exhaust steam: massecuite boiling - exhaust steam; juice heating - vapour I and II and exhaust steam.

A group of factories with total crushing capacity of 680 tc/hr would fit into this class (although certain of the factories would have minor deviations from the specifications listed).

5.04 Group III This group is similar to Group II except that the process utilised is more economical in steam consumption. The main features of this group are:

a) boiler: steam conditions - 21 bar A at 330°C; efficiency based on NCV of bagasse 0.78;

b) turbo-alternator: multistage back pressure turbine with internal efficiency equal to 0.80;

c) prime movers: single stage back pressure turbines with internal efficiency of 0.55; and

d) process: evaporation - quadruple effect utilising 2 bar A exhaust steam: massecuite boiling - exhaust steam: juice heating - vapour I and II and exhaust steam.

A group of factories with total crushing capacity of 1 210 tc/hr would fit into this class (with the same reservation as for Group II factories).

5.05 Group IV This type of factory represents what could be obtained in the Group II and Group III factories by modifying the process department. The main features of this group are:

a) boiler: steam conditions - 21 bar A at 330°C; efficiency based on NCV of bagasse 0.78;

b) turbo-alternator: multistage back pressure turbine with internal efficiency equal to 0.80;

c) prime movers: multistage back pressure turbines with internal efficiency of 0.55; and

d) process: evaporation - quintuple effect utilising 2 bar A exhaust steam: massecuite boiling - vapour I: juice heating - vapour IV, III, II, I and exhaust steam.

5.06 Group V This type of factory represents the ultimate in steam economy that can be achieved in a factory equipped with 31 bar A at 400°C boilers. Several factories belonging to Groups II and III have already installed boilers of this type, and could be converted to Group V factories at relatively low cost. The main features of this group are:

a) boiler: steam conditions - 31 bar A at 400°C: efficiency based on NCV of bagasse 0.82;

b) turbo-alternator: multistage back pressure turbine with internal efficiency equal to 0.80;

c) prime movers: multistage back pressure turbines with internal efficiency of 0.80; and

d) process: evaporation - quintuple effect utilising 2 bar A exhaust steam; massecuite boiling - vapour I: juice heating - vapour IV, III, II, I and exhaust steam.

5.07 Group VI This group represents the ultimate in steam economy that could be envisaged under normal factory conditions. The main features of this group are:

a) boiler: steam conditions - 46 bar A at 440°C: efficiency based on NCV of bagasse 0.84;

b) turbo-alternator: multistage back pressure turbine with internal efficiency equal to 0.80;

c) prime movers: multistage back pressure turbines with internal efficiency of 0.80; and

d) process: evaporation - quintuple effect utilising 2 bar A exhaust steam; massecuite boiling - vapour I; juice heating - vapour IV, III, II, I and exhaust steam.

5.08 The energy balances of factories belonging to Groups II, III, IV, V and VI are given in End Table 7. Before discussing the development options for the various groups of factories it is necessary to review in the next section the electrical energy situation in Mauritius.

6. ELECTRICAL ENERGY PRODUCTION IN MAURITIUS

The Central Electricity Board (CEB)

6.01 CEB controls the supply and distribution of electricity in the island. The production of electricity is derived from three sources:

a) Hydro-electric generators totalling an installed capacity of 23 MW for the production of some 60 GWh annually. A new hydro-electric station is being installed at Champagne River. The installed cap- ity will be 30 MW and the an-ual output is expected to be of the order of 40 GWh.

b) Diesel driven generators totalling a capacity of 132 MW and producting 270 Gwh annually.

c) Purchases from various suppliers, mainly sugar estates which presently supply power during the milling season only. The annual purchases amounted to some 27 GWh in 1980. In 1981 Medine Sugar Estates installed a 10 MW pass-out/condensing turbo-alternator which is expected to produce an additional 20 GWh in the crop season.

6.02 The price of oil having risen sharply in the last few years, and bagasse being a renewable resource available in large quantities, the present tendency is to promote the production of energy from bagasse rather than from oil. On the other hand, coal being cheaper than oil, CEB is considering the installation of a coal fired steam power station at Fort George, Port Louis. Such a power station would be equipped with a boiler designed to burn coal or an equivalent solid fuel, and a condensing turbo-alternator utilising sea water for its condenser. The capacity of the proposed plant would be 30 MW and the steam conditions envisaged are 71 bar A at 500°C. The annual output would be of the order of 170 GWh.

Electricity demand

6.03 Total demand The present annual demand for electricity is 355 GWh. CEB's consultants studied the market and arrived at the conclusion that in the anticipated economic conditions, which may include shortages of liquid fuels, sales of electricity would increase at the rate of 4%/y. Since these conditions are expected to prevail until at least the end of this century, the forecast demand for the future stands as follows:

Year	Demand (GWh)
1980	355
1985	432
1990	525
1995	639
2000	778

6.04 Daily demand The pattern of the daily demand curve is more or less the same throughout the year and is shown in Figure 1. The daily demand can be divided into three categories:

a) the base load averaging 25 MW presently and remaining constant throughout the year;

b) the day load extending from 08.00 hr in the morning until 22.00 hr in the evening. The demand during this period amounts to 50 MW presently; and

c) two peak periods: one in the morning at 11.00 hr and a second, which is the more important one, at 20.00 hr. The maximum demand recorded during the latter period was 83 MW in 1980.

All these loads are expected to rise at the rate of 4%/y. Demand curves for 1980, 1985, 1990 and 2000 are shown in Figure 1.

Forecast loads are therefore as follows:

	Base (MW)	Day (MW)	Peak (MW)
1980	25	50	83
1985	30	61	101
1990	37	74	123
1995	45	90	149
2000	55	110	182

<u>Optimum utilisation of available energy sources</u>

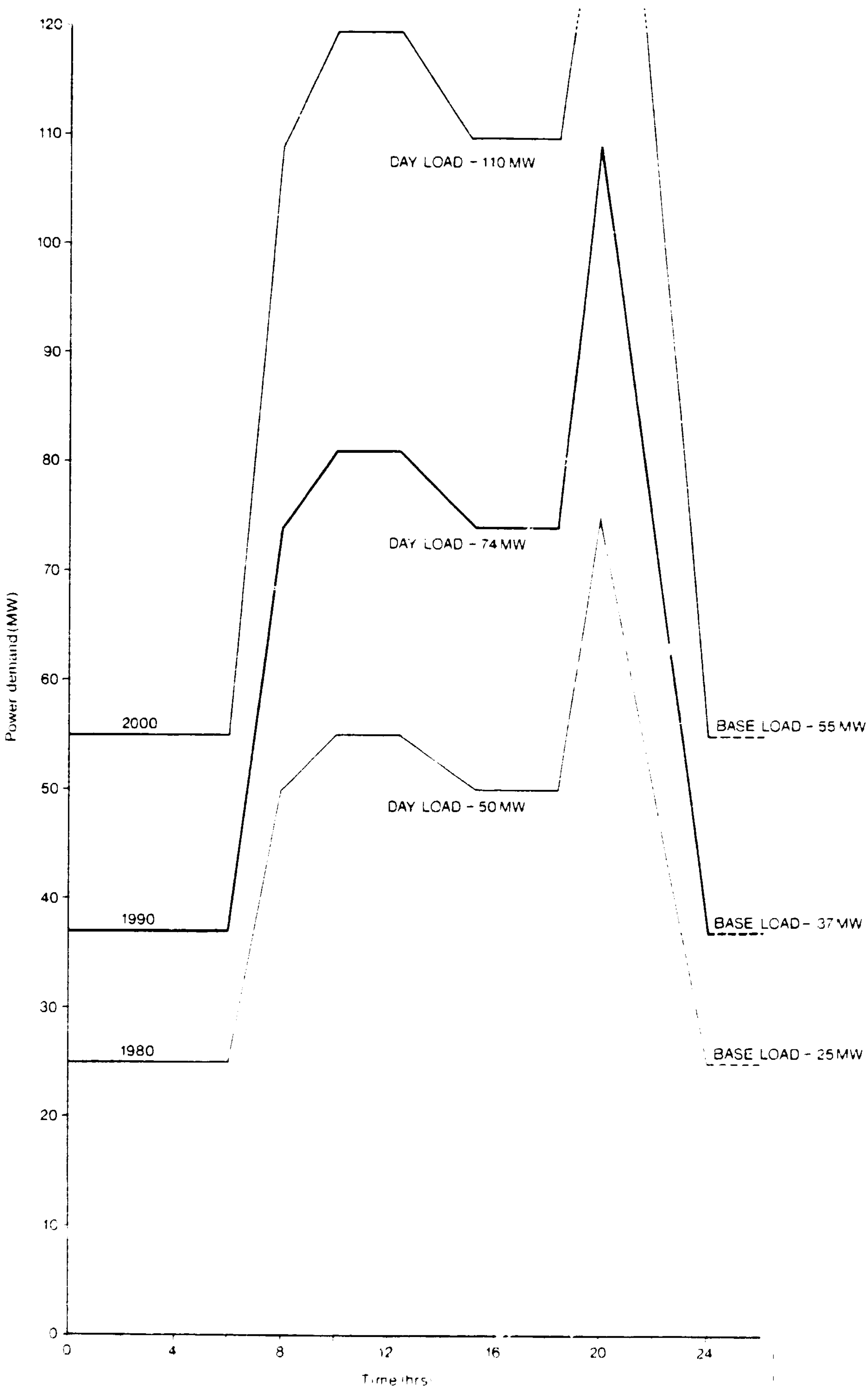
6.05 <u>Peak periods</u> Energy supplied during the peaks is best derived from hydro-electric generators since their response is immediate - they do not require a warming up period. However their utilisation is limited by the availability of water in the dams and this corresponds to only 60 GWh/y at present and 100 GWh/y in the near future. Future maximum available power would be 53 MW at full availability of water. On the day of peak demand in 19[illegible]3 (31 August) only 15 MW of the present capacity of 30 MW was used. When hydro-electric power is insufficient, make up is derived from diesel sets which can be put on load in a relatively short time. In contrast the use of turbo-alternators for this period should be avoided because of:

a) the large amount of fuel that would be wasted in order to bring the boiler to pressure and to warm up the turbine before going on load; and

b) the large additional capital investment required to supply peaks in this manner.

Mauritius: Daily Electricity Demand Curves

Fig. 1



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6.06 Base load This load is ideally suited to turbo-alternators, as they are designed to run continuously and this maximises their utilisation. However, a back pressure turbo-alternator associated with a sugar factory can produce electricity only when the factory is operating. This means that if back pressure energy is not produced while the factory is working then it will not be produced at all. Since the energy conversion of a back pressure turbo-alternator is of the order of 80% of the net energy content of the fuel, priority should be given to back pressure electricity exported by the sugar factories to meet the base demand. During the out-of-crop season and in-crop stoppages, CEB could operate its own thermal power station (if installed) fired by coal or bagasse, and in the last resort, its diesel sets which are more expensive to run.

6.07 Day load

a) This portion of the load covers part of the day only and therefore back pressure energy from the sugar factories which operate round the clock is ill adapted to meet it. However, pass-out/condensing turbo-alternators could fulfil this function very well. During the off-peak periods, the boilers would generate only enough steam to operate the HP section of the prime movers and turbines and supply low pressure steam to the process section. A surplus of bagasse would then be obtained which would be kept in the bagasse store for later use. When the demand increases during the day, more steam would be generated thus burning all the bagasse being produced, plus the bagasse which had accumulated in the store during the night. This additional steam after passing through the HP section of the turbine would be fed into the LP section, thus producing the same amount of energy as in a conventional condensing turbine. However the boiler being on load and the turbine being warm and turning, the expensive wastages incurred when starting up a power station would not occur.

b) A coal fired power station meeting this day load would behave differently. During the night (22.00 hr to 08.00 hr), and provided the sugar factories are producing the base load, the boiler would have to be banked, ie the steam production would be cut down so as to run the turbine on little or no load. However, this operation would be wasteful of imported coal.

c) Diesel sets with their high running costs should be avoided as much as possible

6.08 Out-of-crop If, as now, the sugar factories only supply electricity during the crop season, CEB must have sufficient capital equipment at its disposal to generate the entire consumption between crops. This effectively reduces the value of electricity supplied to CEB during crop harvesting to the cost of the fuel which otherwise would have been imported. On the other hand, if the sugar factories could supply either electricity or fuel year-round, CEB's capital investment would be less, and the price it would be prepared to pay the sugar factories would be higher. It is therefore in the interests of both the sugar factories and CEB to investigate ways of achieving this.

Development strategy for sugar industry power generation

6.09 The technical factors discussed in paragraphs 6.05 to 6.08 indicate that the sugar factory power generation plant can be utilised most efficiently to meet the following portions of the total electricity demand:

	in-crop	out-of-crop
Base load	back pressure TA	condensing TA
Day load	condensing TA	condensing TA.

The condensing turbo-alternators could be sited either at the sugar factories or at a central CEB power station. In either case practical methods would be needed to store and handle bagasse on a fairly large scale, to enable power to be generated throughout the year. Year-round power generation from bagasse offers the greatest potential benefits to the sugar factories, CEB and the national economy.

6.10 The feasibility of bagasse storage is of crucial importance in defining power generation strategy. Accordingly recent developments in this technology are reviewed in the following section. Provided that bagasse storage is feasible, then year-round power generation is the preferred strategy. If long-term bagasse storage is not feasible with present technology, then in-crop power generation offers an alternative development strategy which would in some respects be simpler to implement and manage, but which would not result in comparable benefits to the nation.

7. STORAGE OF BAGASSE

Alternative systems

7.01 The sugar industry throughout the world previously had little incentive to develop large-scale, long-term storage systems for bagasse. Traditionally, bagasse has been used (usually burned) at the same rate as it is produced. Most sugar factories require only a small store of loose bagasse to cover their fuel needs during mill stoppages and for restarting the factory following a maintenance shut-down.

7.02 Storage of bagasse is severely constrained by its physical characteristics. It contains on average 50% water; this facilitates fermentation processes and may lead to spontaneous combustion, particularly when stored in large piles. It has a low bulk density, requiring large and therefore expensive stores. Dry bagasse is implicated in the lung disease bagassosis. These factors also limit the feasibility of transporting bagasse.

7.03 Large-scale storage is practised in those paper or fibre-board industries using bagasse as a raw material. The principal methods adopted are as follows 1/:

a) Bale storage. The bagasse is fed to a baling press and the bale is secured with wire. The weight of the bale varies from 30 kg (Taiwan) to 125 or even 800 kg (USA). The bales are stacked, manually or mechanically, and sheeted. A number of separate stacks are advisable to prevent the (almost inevitable) fires from spreading. The system involves high costs of labour and/or machinery during the preparation and the use of the stacks. The presence of baling wire in the material is frequently troublesome.

b) Wet bulk storage. Several methods have been described, of which the Ritter process is the best known. A so-called biological liquor is recycled over a bulk storage pile of wet bagasse in order to eliminate the dust and fire hazards and to keep the fibre soft. This storage method is evidently not appropriate for bagasse to be used as fuel.

1/ Atchison, J E (1971). Review of progress with bagasse for use in industry. ISSCT XIV Congress, 1971.

c) Dry storage. On a comparatively small scale (ie fibre-board plants rather than paper mills) the depithed fibre has been dry stored. To reduce the fire risk, dust and handling problems, the fibre is compressed into large mats, briquettes or pellets. None of these processes appears to have been entirely satisfactory.

7.04 Considerable development work would be needed to establish a practical method for storing bagasse fuel. One interesting process, the Woodex Process, patented by the Bio-Solar Research and Development Corporation of Eugene, Oregon, USA, is currently installed in the Haina Factory of Davies Hamakua Sugar Company, Hawaii. This process appears to offer the prospect of yielding a dust-free, relatively high density, free-flowing pelleted bagasse. Preliminary information on the process (which is currently starting its first full year of operation) is provided in the following paragraphs.

<u>The Woodex process for pelletisation of bagasse</u>

7.05 The Woodex process involves two key stages:

a) drying of bagasse by making use of the energy content of the boiler flue gases; and

b) compressing the dried and sieved bagasse fines into a solid fuel having a bulk density of 650 kg/m^3.

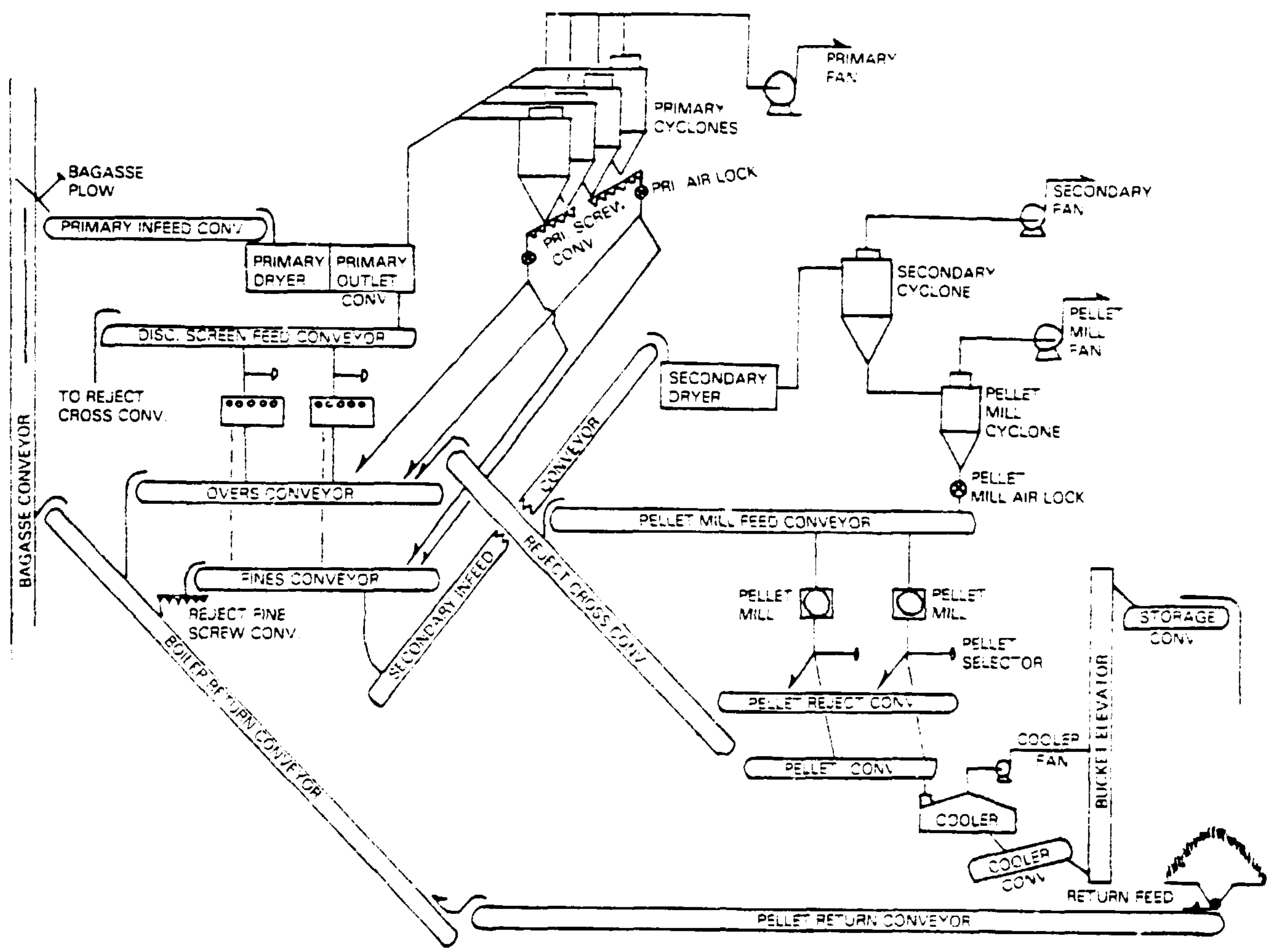
Bagasse from the mills has a moisture content of 50%. It is first dried to a moisture content of 35% in a rotary dryer using the boiler flue gases. The semi-dried bagasse is then screened into coarse and fine particles, the former going as fuel to the boiler while the latter are further dried in a second rotary dryer to a moisture content of 10%. At this stage the dried bagasse is compressed into pellets by a machine of the type used for pelleting animal feeds. A layout of the Woodex process is shown at Figure 2.

7.06 The Woodex process is reported to have the following advantages:

a) Drying the bagasse with flue gases lowers the temperature of the gases leaving the chimney (to less than 70°C in the Hawaii plant) thus using energy that would otherwise be wasted. Considering the boiler house and Woodex plant as a whole, and since everything else has remained unchanged, there is a net gain in the efficiency of the system. However with efficient boilers it is not certain whether there would be enough waste heat in the flue gases to dry all the bagasse to 35% moisture.

Layout of Bagasse Pelleting Plant

Fig. 2



Source : SUGAR y AZUCAR, August 198?.

The efficiency of combustion of bagasse containing 35% moisture, and of pellets containing 10% moisture is improved, as compared with that of raw bagasse containing 50% moisture. This in turn improves the efficiency of the boiler.

b) Woodex pellets are a concentrated solid fuel of 10.25×10^6 kJ/m^3 (cf coal 26.05×10^6 kJ/m^3). A sugar factory utilising this process could store its surplus of bagasse as pellets, in a relatively small silo.

c) The bulk density of the pellets is comparable with that of sugar (650 v/s 800 kg/m^3), so it would be possible to use the same vehicles for transporting pellets (out-of-crop) as are used for transporting bulk sugar during the crop.

d) Pellets would be easy to handle and free-flowing enough to replace coal or bagasse in boilers designed for these fuels.

e) Many of the items used in a Woodex plant could be manufactured locally under licence, thus reducing the costs of manufacture and transport.

f) A comparison of the energy contents of bagasse at various moisture levels is given below:

	kJ/kg	kJ/kg dry matter
Raw bagasse containing 50% moisture	7 641	15 282
Semi-dried bagasse containing 35% moisture	10 686	16 440
Pellets containing 10% moisture	15 763	17 514

See Annex 6.

Utilisation of bagasse pellets

7.07 The average distance over which the pellets would have to be transported if delivered to a central power station in Port Louis is 33 km (21 m) (Annex 7).

In the case of factories delivering their pellets to two or three regional power stations, this average distance would fall to 16.5 km (10 m). The cost of transporting pellets is taken as equal to that of transporting sugar ie Rs1.61/t-km ($0.16). Costs are therefore:

	Rs/t	$/t
Central	53.28	5.19
Regional	26.64	2.60

7.08 The quantities of pellets obtainable from 100 tc/hr factories equipped with Woodex pelletising plants are:

	t/hr
Group IV	4.522
Group V	4.423
Group VI	4.385

See End Table 8.

7.09 The amounts of condensing electrical energy obtainable from 1 t pellets under various steam and vacuum conditions are:

	kWh
Groups II, III, IV	741
Group V	848
Group VI	932
CEB coal fired station	1 056

See End Table 9.

Opportunity costs of bagasse and pellets

7.10 Presently CEB is relying on its diesel alternators to produce the bulk of the national electric demand. In 1980 this was 233 GWh (68%) out of CEB's total production of 342 GWh. The average fuel consumption of these sets is about 3.5 kWh/ℓ (16 kWh/gal). The price of the fuel oil has just reached Rs2.6/ℓ (Rs11.8/gal - $0.25/ℓ). Therefore the cost of fuel oil per kWh is Rs0.74 ($0.072). Based on this figure, the opportunity costs of bagasse are as follows:

	---------Rs/t-------		-------$/t--------	
	Pellets	Bagasse	Pellets	Bagasse
Group IV	520.66	212.02	50.79	20.68
Group V	599.74	249.45	58.51	24.34
Group VI	675.39	280.75	65.89	27.39

See End Table 10.

7.11 CEB is considering the installation of a coal-fired steam power station at Port Louis. The landed cost of coal is presently Rs622/t ($61). Based on this price, the opportunity cost of bagasse pellets if used in the new station, would be Rs309.86/t ($30.23) as shown in End Table 11. The opportunity cost of bagasse would be Rs126.18/t ($12.31).

7.12 At this stage it is difficult to calculate the cost of production of pellets from bagasse since the process is new, and there is only one plant in operation in the world. The only figures obtained so far from Hawaii are:

a) The capital investment of the prototype Woodex unit installed at Haina comprising dryers, conveyors, pelletising machines, fans, ductings etc plus building and silo represented some Rs29 M ($2.8 M). The manufacturers are confident that the process can be simplified, and if the equipment were built locally under licence the cost could be brought down to Rs17-24 M ($1.7-2.3 M).

b) The annual production of pellets at Haina is expected to be of the order of 20 000 t from 112 000 t bagasse or 450 000 t cane.

c) The whole plant is fully automated and needs only two operators per shift. In Mauritius, a factory operator of this grade would earn Rs25 000 ($2 400) annually.

d) The electric energy consumption of the Haina Woodex plant was found to be 90 kWh/t pellets produced.

e) The expected life of the equipment is assumed to be 25 years.

7.13 In Section 8 a development option is identified in which all 15 Group IV factories would instal Woodex plants to yield 227 340 t pellets per year. The capital cost of this is estimated at Rs307 M ($30 M) (End Table 13).

7.14 Based on the preliminary data from Hawaii the cost of production in Mauritius of one year's Woodex pellets (227 340 t) is tentatively estimated as below:

	Rs'000
Depreciation of equipment: 4%	12 280
Maintenance: 2%	6 140
Insurance premiums: 1%	3 070
Labour 1/	1 500
Interest on capital utilised: 10%	30 700
Total	53 690
	$ 5 238 000

Estimated cost of production of pellets is Rs230/t ($22.50). The process itself requires 90 kWh/t pellets and this would have to be deducted from the total production of electricity for the grid.

1/ 15 plants with two operators on each of two shifts, Rs25 000/man year.

7.15 It is evident that the high reported capital costs of installing Woodex plants at 15 factories result in a cost of production of the pellets which is close to the value ascribed to the pellets in paragraphs 7.10 and 7.11. Thus considerable further evaluation of this process, particularly its costs, is required before investment decisions on its use can be taken. It is estimated that a feasibility study would take 10 man-months and would cost Rs640 000 ($63 000). The pilot plant is estimated at Rs29 M ($2.83 M).

8. ELECTRICAL ENERGY PRODUCTION FROM THE SUGAR INDUSTRY FOR THE WHOLE YEAR

Introduction

8.01 This section is based on the assumption that some form of bagasse storage proves technically and financially feasible. As noted in 7.15 this is by no means certain. If bagasse storage does not prove feasible, then in-crop energy production, as described in Section 9, becomes the only option.

8.02 In order to increase the production of electrical energy from bagasse, the logical sequence is as follows:

Step 1: Reduction of the internal energy consumption of the factories by improving the energy efficiency of process sections, resulting in the production of a larger excess of bagasse;

Step 2: Adoption of a drying and pelleting process (Woodex or equivalent) in order to:

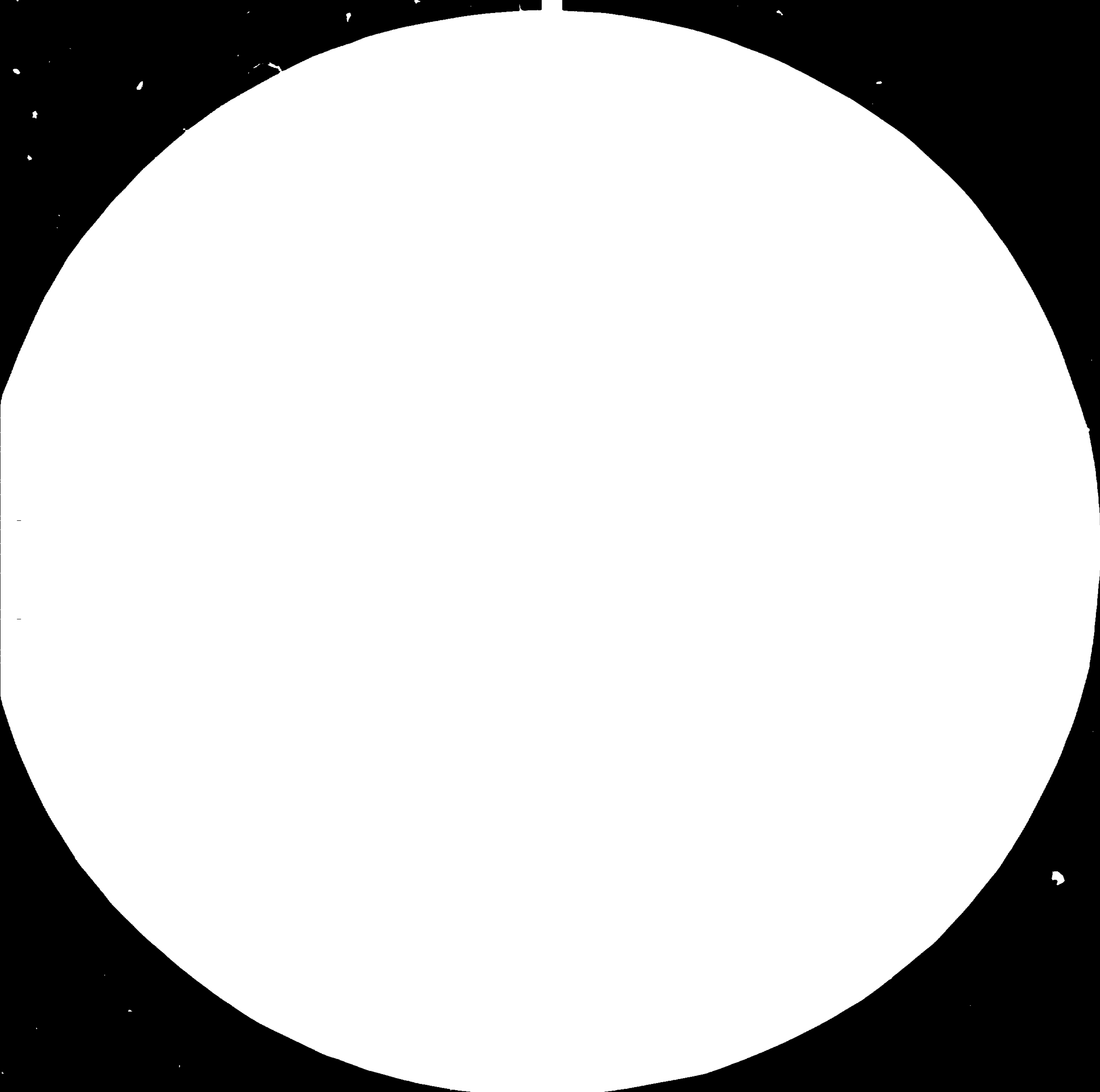
a) improve the overall thermal efficiency of the factories; and

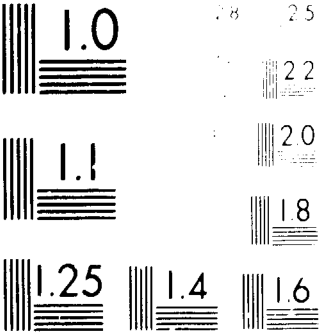
b) transform the surplus of bagasse available into a concentrated, storable, transportable, free-flowing fuel.

Step 3: Production of electrical energy from the pellets obtained, by means of power stations. Three sub-options are examined in para 8.11.

These steps are examined in greater detail below and in order to evaluate the costs incurred, the following figures have also been worked out:

a) the cost of production of electrical energy from coal; and





1.0
2.8
2.5
2.2
1.1
2.0
1.8
1.25
1.4
1.6

b) the maximum amount of electrical energy obtainable from the sugar industry under ideal conditions.

Present position

8.03 The existing factories can be classified as follows:

Group	Number of factories	Total capacity tc/h
I	6	460
II	6	680
III	9	1 210

The duration of crop harvesting is taken as 134 days or 2 660 hrs (para 2.16). From the figures derived in End Table 7 the surplus electrical energy obtainable for export to the grid would be as follows:

a) Electrical power derived from back pressure turbo-alternators:

Factories		kW
Group I		= negligible
Group II	$= \frac{680}{100} \times 1\ 357$	= 9 228
Group III	$= \frac{1\ 210}{100} \times 723$	= 8 748
Total		17 976

Energy obtainable during harvesting period crop

$$= \frac{17\ 976 \times 2\ 660}{10^6} = 47.816 \text{ GWh}$$

b) Surplus of bagasse obtained annually from:

Factories		Bagasse t
Group I	=	negligible
Group II	$= \frac{680}{100} \times 2.019 \times 2\ 660 =$	36 520
Group III	$= \frac{1\ 210}{100} \times 4.643 \times 2\ 660 =$	149 440
Total		185 960

8.04 These outputs have never been achieved in practice and the total energy exported to the grid amounted to only 26.763 GWh in 1980.

Step 1

8.05 The first step in increasing the surplus of energy from bagasse is to minimise the energy demand of the factories by improving the mode of operation of their process departments. In practice this would mean the transformation of Group II and III factories to Group IV.

8.06 There is no advantage in transforming the process departments of Group I factories because, being equipped with low pressure boilers, their live steam demand is equal to or even higher than their process steam demand. Hence reducing the process demand would just increase the surplus of exhaust steam already available, without any possibility of producing electricity from it.

8.07 The new factory classification would then become as follows:

Group	Number of factories	Total capacity tc/h
I	6	460
IV	15	1 890

a) Electrical power derived from back pressure turbo-alternators:

Factories		kW
Group I		negligible
Group IV	$\frac{1\ 890}{100} \times 194$	3 667

Back pressure energy obtainable during crop =

$$\frac{3\ 667 \times 2\ 660}{10^6} = 9.754 \text{ GWh}$$

b) Surplus of bagasse obtainable from:
Factories

Group I = negligible

Group IV $= \frac{1\ 890}{100} \times 6.838 \times 2\ 660 = 343\ 774$ t

8.08 Cost of implementation of Step 1: Step 1 development concerns essentially the process departments of the factories. The dimensioning and steam demand of the quintuple effect evaporators and of the juice heaters of the 100 tc/hr Group IV (V or VI) factories are calculated in Annex 8.

End Table 12 shows:

a) the existing equipment in each factory;

b) the additional equipment required to attain Group IV, (V or VI) status;

c) the suggestions prescribed for this transformation; and

d) the capital investment required for this transformation.

The capital cost of implementing Step 1 is as follows:

	Foreign exchange component	Local	Total
Rs Million	10.29	1.14	11.43
$ Million	0.9	0.2	1.1

8.09 Implementing Step 1 alone simply results in an increased bagasse surplus which has little value unless it is followed by the subsequent steps necessary for its utilisation.

Step 2

8.10 The next step would be the widespread adoption of bagasse storage systems such as the Woodex process by all Group IV factories. The factories classification would remain unchanged from Step 1.

a) The electrical power derived from back pressure turbo-alternators remain unchanged but the power consumption of the factories would increase and there would be a net deficit of back pressure energy:

$$20.461 - 9.754 = 10.707 \text{ GWh}$$

b) Surplus of bagasse pellets obtainable from:

Factories

Group I = Nil

Group IV $\frac{1\ 890}{100}$ x 4.522 x 2 660 = 227 340 t

The capital investment costs of Step 2 would be:

	Foreign exchange component	Local	Total
Rs Million	276	31	307
$ Million	27	3	30

End Table 13 shows the individual factory investment costs.

Step 3

8.11 After the implementation of Steps 1 and 2, the Mauritius sugar industry would have available an excess of pellets amounting to 227 340 t annually. In order to produce electrical energy from these pellets, three alternatives are considered:

Option A

The bagasse pellets could be burned, in place of coal, at CEB's proposed coal fired power station to be sited at Fort George, Port Louis.

Option B

Three 10 MW regional power stations specially designed for bagasse (in-crop) and bagasse pellets could be installed in existing sugar factories; this would reduce transport costs of pellets, and would make use of the facilities already available, such as management, maintenance and supervisory assistance.

Option C

Equipment already installed in the sugar factories would be used. Existing boilers could be converted at low cost to operate on pellets and/or bagasse. Some pass-out/condensing turbo-alternators are already in operation during the cropping season: their operation could be extended to the intercrop as well.

8.12 Option A If the CEB goes ahead with its project of installing a coal fired power station at Port Louis, bagasse pellets could be used as a substitute for coal. The power station would operate at 71 bar A at 500°C.

The total electrical energy obtainable from the 227 340 t of pellets

= 1 056 x 227 340 = 240.071 GWh

Back pressure electrical energy production during the crop: = 9.754 GWh

Electrical energy consumed by the Woodex plants = 20.461 GWh

Hence net electrical energy derived from bagasse = 229.364 GWh

This plant could be utilised for 320 days/y ie 320 x 24 = 7 680 hrs

The average power output would be $\frac{229.304 \times 10^6}{320 \times 24}$ = 29 845 kW

(Note: The base load of the CEB is expected to exceed 31.6 MW by 1986).

This option would generate 229.364 GWh from 227 340 t pellets.

The capital costs of Option A would be:

	Foreign exchange component	Local	Total
Rs Million:			
Step 1	10	1	11
Step 2	276	31	307
Step 3 Option A	332	18	350
	618	50	668
$ Million:	60.3	4.9	65.2

The annual costs of the three steps are as follows:

	Rs'000	Rs/kWh	$'000	$/kWh
Step 1	330	0.002	32	
Step 2	22 760	0.100	2 220	
Step 3 Option A	11 500	0.050	1 122	
	34 590	0.152	3 374	0.015
Depreciation	26 740	0.116	2 609	0.011
Interest	66 840	0.292	6 521	0.028
	128 170	0.560	12 504	0.054

8.13 Costs of production are shown in End Table 14 on the assumption that the purchase price of bagasse is zero.

8.14 Option B The second option for producing electrical energy from the pellets would be the installation of three 10 MW regional power stations housed inside existing sugar factories. The power stations utilised would be of the Group VI factory type operating at 46 bar A at 440°C.

Total electrical energy obtained from the 227 340 t of pellets:

227 340 x 932 = 211.881 GWh

Back-pressure electrical energy produced during the crop 9.754 GWh

Electrical energy consumption of Woodex plant 20.461 GWh

Hence net amount of electrical energy produced from bagasse 201.174 GWh

If utilised during 320 d/y the average power output would be:

$$\frac{201.174 \times 10^6}{320 \times 24} = 26\ 194 \text{ kW}$$

which is compatible with the current CEB's base load demand.

Costs of capital and production are shown in End Table 15.

8.15 Option B would generate 201.174 GWh from 227 340 t pellets.

The capital costs of Option B are:

	Foreign exchange component	Local	Total
Rs Million:			
Step 1	10	1	11
Step 2	276	31	307
Step 3 Option B	228	12	240
	514	44	558
$ Million:	50.1	4.3	54.4

The annual costs of the three steps are as follows:

	Rs'000	Rs/kWh	$'000	$/kWh
Step 1	330	0.002	32	
Step 2	16 848	0.084	1 644	
Step 3 Option B	8 200	0.041	800	
	25 378	0.127	2 476	0.012
Depreciation	22 340	0.121	2 180	0.012
Interest	55 840	0.268	5 448	0.026
	103 558	0.516	10 104	0.050

Costs of production are shown in End Table 15.

8.16 Option C In this alternative the capital investment is reduced to a minimum by making use of the equipment already installed at the sugar factories. Different possible combinations can be envisaged but the one given will illustrate the advantages and disadvantages.

8.17 At present there exist in the Mauritian sugar factories five 50-70 t/h 31 bar A at 400°C boilers, operating at 21 bar A at 350°C. There is one 50 t/h 10 MW condensing turbo-alternator utilising 31 bar A at 400°C already in operation at Medine. Option C would consist in installing two additional 10 MW condensing sets at two factories equipped with 31 bar A boilers (say Savannah and Mon Desert Alma). An alternative would be the 20 MW set currently under study for F.U.E.L. One option being examined is for this set to operate at 46 bar A. This would increase production of electricity under Option C to 194 GWh. The boiler capacity required to operate a 100 tc/hr Group IV factory is given in Annex 9. The condensing electrical energy produced and the amount of pellets consumed per ton of steam at 31 bar A at 400°C are given in Annex 10.

8.18 The condensing electricity produced and the pellets consumed would be as follows:

	Condensing electricity kW	Pellets used t/h
Medine	9 262	10.9
Mon Desert	5 916	7.0
Savannah	4 495	5.3
	19 673	23.2

See End Table 16.

8.19 The total performance of Option C is:

a) Production of pellets — 227 340 t

Amount of pellets utilised during crop:
23.202 x 2 660 = 61 717 t

Amount of pellets utilised during intercropping period — 165 623 t

b) Total amount of condensing electrical energy obtained from the 227 340 t of pellets:

i) during crop: 2 660 h x 19 673 — 52.330 GWh
ii) during intercrop: 165 623 x 848 — 140.448 GWh
192.778

Back-pressure electrical energy produced during the crop — 9.754 GWh

Electrical energy consumption of Woodex plants — 20.461 GWh

Hence net amount of electrical energy produced from bagasse — 182.071 GWh

If utilised during 320 d/y the average power output would be:

$$\frac{182.071 \times 10^6}{320 \times 24} = 23\ 707 \text{ kWh}$$

8.20 This option would generate 182.071 GWh from 227 340 t pellets.

Total capital costs of Option C would be:

	Foreign exchange component	Local	Total
Rs Million:			
Step 1	10	1	11
Step 2	276	31	307
Step 3 Option C	76	4	80
	362	36	398
$ Million:	35.3	3.3	38.8

The annual costs of the three stages are as follows:

	Rs'000	Rs/kWh	$'000	$/kWh
Step 1	330	0.002	32	
Step 2	16 848	0.093	1 644	
Step 3 Option C	3 400	0.018	332	
	20 578	0.113	2 008	0.011
Depreciation	15 940	0.088	1 555	0.008
Interest	39 840	0.219	3 887	0.021
	76 358	0.420	7 450	0.040

Costs of production are shown in End Table 17.

Cost of production of electrical energy from coal

8.21 This cost of production is based on the same energy output as in Option A, ie 229.364 GWh annually.

Coal utilised to produce electrical energy = $\frac{283}{512}$ kg/kWh

(see End Table 11)

Total weight of coal utilised annually: $\frac{229.364 \times 10^6 \times 283}{512 \times 1000}$

= 126 777 t

The capital cost of a coal fired station would be:

	Foreign exchange component	Local	Total
Rs Million:	437	23	460
$ Million:	42.6	2.3	44.9

The annual costs of electrical energy from coal are as follows:

	Rs'000	Rs/kWh	$'000	$/kWh
Coal	78 855	0.344	7 693	-
Other irect costs	14 800	0.064	1 444	-
	93 655	0.408	9 137	0.040
Depreciation	18 400	0.080	1 795	0.008
Interest	46 000	0.200	4 488	0.020
	158 055	0.688	15 420	0.068

Estimated costs of production are shown in End Table 18.

Theoretical maximum amount of electrical energy obtainable from bagasse

8.22 This hypothetical case assumes that all factories would be transformed into Group VI factories, that the Woodex process would be universally adopted in all of them, and that the pellets would be utilised in a central power station.

Factory classification would become: Group VI factories
total capacity : 2 350 tc/hr

a) Back pressure electricity produced during crop:

i) Power output: $\frac{2\ 350}{100} \times 2\ 622 = 61\ 617$ kW

ii) Electrical energy produced: 61 617 x 2 660 = 163.901 GWh

b) Amount of pellets produced: $\frac{2\ 350}{100} \times 4.385 \times 2\ 660 = 274\ 106$ t

Electrical energy consumption of Woodex plants:

90 x 274 106 = 24.670 GWh

c) Condensing electrical energy obtainable from the pellets, if utilised in a central power station utilising 71 bar A at 500°C steam:

274 106 x 1 056 = 289.456 GWh

Hence total electric energy exported to the grid:

163.901 - 24.670 + 289.456 = 428.687 GWh

If utilised during 320 d/y the average power output would be:

$$\frac{428.687 \times 10^6}{320 \times 24} = 55\ 819 \text{ kW}$$

Summary

8.23 The key data from the above paragraphs are summarised below:

	Average power output MW	Energy generation GWh	Capital cost Rs M	Annual cost Rs M	Unit cost Rs/kWh
Power generation from coal a/	29.9	229	460	158	0.688
Theoretical potential from bagasse b/	55.8	429	-	-	-
Present industry					
- actual		27	-	-	-
- potential		48	-	-	-
Option A	29.9	229	668	128	0.560
Option B	26.2	201	558	104	0.516
Option C	23.7	182	398	76	0.420

a/ Costings based upon the same energy output as Option A.
b/ No costings given as this is a purely theoretical figure: its achievement would necessitate massive investment in the sugar industry.

9. ELECTRICAL ENERGY PRODUCTION FROM THE SUGAR INDUSTRY IN THE CROP SEASON ONLY

Starting position - Step 1 (crop season)

9.01 If no practical means were found of economically processing, storing and transporting bagasse for year-round use in power generation, a programme of improving existing sugar factories would need to be set under way in order to maximise electricity generation at the sugar factories during the crop. This would represent a less attractive option because the capital costs would be high (given the need for major plant modifications at all factories) and the value of the electricity, produced during 134 days only, would be low.

9.02 The present position is outlined in paragraph 8.03; Step 1 (crop season) would be the same as Step 1 for the year-round plan outlined in paragraphs 8.05 to 8.08.

Step 2 (crop season)

9.03 The next development would be the transformation of those factories equipped with 31 bar A boilers (but presently limiting their steaming pressure to 21 bar A) into Group V factories. The classification of the factories would then become:

Group	Number of factories	Total capacity tc/h
I	6	460
IV	10	1 260
V	5	630

a) Electrical power derived from back pressure turbo-alternators:

Factories		kW
Group I		Nil
Group IV	$\frac{1\ 260}{100} \times 194 =$	2 444
Group V	$\frac{630}{100} \times 1\ 856 =$	11 693
Total		14 137

Electrical energy produced during crop = $\frac{14\ 137 \times 2\ 660}{10^6}$ =37.604 GWh

b) Surplus of bagasse obtainable from:

Factories			Bagasse t
Group I	=		negligible
Group IV	=	$\frac{1260}{100} \times 6.838 \times 2\ 660 =$	229 182
Group V	=	$\frac{630}{100} \times 6.644 \times 2\ 660 =$	111 340
Total			393 846

c) Electrical energy obtainable from this bagasse if utilised in a condensing turbo-alternator installation with steam at factory conditions:

Group IV factories:	229 182 x 359 =	82.276 GWh
Group V factories:	111 340 x 411 =	45.761 GWh
Total		128.037 GWh

d) Total energy from back pressure and condensing turbo-alternators is 37.604 + 128 037 = 165.641 GWh.

Theoretical maximum energy generation during crop only

9.04 The ultimate development of the sugar industry, with regards to electrical energy production, would be reached when all the sugar factories have been transformed into Group VI factories. This condition is unlikely to be reached in practice because of the very large investment costs, but the following calculations give an indication of the maximum amount of electrical energy obtainable from the sugar industry during the crop only.

a) Power obtainable from back pressure turbo-alternators during the cropping season:

Group VI factories: $\frac{2\ 350}{100} \times 2\ 622 = 61\ 617$ kW

Energy produced during cropping season = 61 617 x 2 660
= 163.901 GWh

b) Surplus of bagasse obtainable from:

Group VI factories: $\frac{2\ 350}{100} \times 6.572 \times 2660 = 410\ 816$ t

c) Electrical energy obtainable from this bagasse if utilised in a condensing turbo-alternator installation utilising steam at factory conditions:

Group VI factories: 410 816 x 452 = 185.689 GWh

d) Total energy from back pressure and condensing turbo-alternators is 163.901 + 185.689 = 349.590 GWh.

Comparison of in-crop energy production with demand

9.05 As indicated in Chapter 6, the demand projection are as follows:

	Base load, MW	Day load, MW
1980	25	50
1990	37	74
2000	55	110

Power developed in back pressure turbo-alternators may only be used to meet the base load; any excess base load and the day load increment must be supplied by condensing turbo-alternators.

9.06 From 9.03 (a) the available back pressure power is 14.1 MW; this amounts to 37.604 GWh over the crop season of 2 660 h. The balance of the base load (over 2 660 h) plus the day load increment (from 08.00-22.00 hr for 134d = 1876 h) can be supplied from condensing turbo-alternators. The available electrical energy is shown in 9.03 c) to be 128.037 GWh. A comparison is given below of this energy in relation to demand.

	Base load demand in crop GWh	Back pressure turbo-alternators supply 2 640 h GWh	Balance (1-2) GWh	Incremental day demand in crop (1 876 h) GWh	Total 3+4 GWh	Available condensing energy GWh
1980	66.5	37.6	28.9	46.9	75.8	128.0
1990	98.4	37.6	60.8	69.4	130.2	128.0
2000	145.8	37.6	108.2	102.8	211.0	128.0

9.07 It is apparent that this option could supply all the base and day loads anticipated until about 1990. Expressed another way, the bagasse available could not be fully utilised until 1990.

This option does not save CEB any capital investment as it would continue to have to meet all out-of-crop energy demands from its own plant. It would also be expensive in terms of capital investment as each factory involved in the scheme would require to be equipped with an over capacity boiler as well as with a condensing turbo-alternator and auxiliaries.

10. FINANCIAL AND ECONOMIC ANALYSES

10.01 A full financial analysis of CEB is beyond the terms of reference of this study. The following returns on the power stations proposed in Section 8 (year round options) are therefore only as good as the assumptions made, as to firstly the amount of electricity generated, and secondly the effect on other parts of the system. These assumptions are:

a) the power stations will generate the amounts indicated in Section 8 as being their full production : except that in the first year of operation they will generate two-thirds that amount;

b) no account has been taken of other parts of the system : these would vary little between the options.

10.02 The internal rates of return indicated are therefore quite high, but this does not invalidate the conclusions drawn. They are:

Type of power station	Option	IRR %
Central coal fired		19.8
Central bagasse pellet fired	A	21.3
Regional bagasse pellet fired	B	22.6
Factory bagasse pellet fired	C	26.4

These assume a zero cost of bagasse.

10.03 The conclusions are:

a) the high capital cost of the bagasse pelletisation plants gives a greater overall investment, which is offset by lower operating costs;

b) regional bagasse pellet power stations have an advantage in return on investment, although they produce less electricity than the central station;

c) even though the factory bagasse pellet power stations produce even less electricity than the other options, the fact that much of the investment has already been made gives them a high return on that which is still needed: a further, unquantified, benefit is the electricity generated during crop before bagasse pellets become available.

10.04 These conclusions are confirmed by calculations of net present values (NPVs). Even as low as 10% interest, Option C has the highest NPV; Option B is then less attractive than Option A. NPVs at 10% and 15% are:

Type of power station	Option	NPV RSM 10%	NPV RSM 15%
Central coal fired	-	380	134
Central bagasse pellet fired	A	591	234
Required bagasse pellet fired	B	577	246
Factory bagasse pellet fired	C	602	293

10.05 Comparison of the cash movements of the coal-fired central station with Options A and B shows that the investment in Woodex produces substantial returns in the form of coal not consumed:

	IRR %
Option A v. coal-fired	23.6%
Option B v. coal-fired	34.4%

(The total investment in Option C is only slightly more than that in the coal-fired station, so the figure for IRR approaches infinity).

10.06 A full description of the assumptions made in the analysis is at Appendix 11.

11. CONCLUSIONS

Electrical energy production

11.01 There is a tremendous scope for increasing the production of electrical energy from bagasse. The present production from the sugar factories amounts to 27 GWh only, whilst the maximum possible production is estimated to be 429 GWh. Thus the present utilisation of bagasse for power generation represents only 6.3% of what could theoretically be achieved.

This target figure has been derived to provide a perspective; it should not be the immediate objective as it implies the complete transformation of the existing factories into Group VI. Since none of the presently installed boilers and turbines correspond to this standard, the investment involved would be enormous and completely unrealistic unless it were part of a major industry reorganisation programme. However, it is strongly recommended that all new boilers and turbines purchased to replace ageing equipment should conform to Group VI standards.

Pelletisation

11.02 All developments to yield year round power from bagasse start with Steps 1 and 2 ie the reduction of the energy consumption of the factory followed by converting the bagasse into a concentrated, transportable solid fuel. So far the only reportedly successful method of achieving Step 2 is the Woodex process under development in Hawaii. This process will require careful examination before being adopted on a large scale in Mauritius.

If found unsatisfactory, some equivalent means should be developed to render bagasse economically transportable, otherwise there would be much reduced scope for development. The only other means of producing electrical energy from bagasse would be utilisation of the surplus of bagasse during the crop only which involves installing high pressure boilers and condensing turbo-alternators at each sugar factory. The cost of this investment is likely to be prohibitive and the power output is less advantageous to CEB since production would be concentrated into 134 days, instead of being spread over 320 days.

Transportation of bagasse pellets represents only Rs0.050/kWh produced when the pellets are transported to a central power station in Port Louis, and Rs0.031/kWh when utilised in regional power stations. These figures are small and the difference between them insignificant. Therefore transport of pellets is a factor which should not influence the choice between central and regional power stations.

Overall energy position

11.03 In Mauritius the only local sources of energy are:

a) hydro-electric generation which will amount to 100 Gwh anually, without any possibility of expansion;

b) energy from bagasse (pellets) amounting presently to 27 GWh annually, but with a possibility of rising under Option A to 229 GWh annually in a near future, and to 429 GWh in the distant future.

The expected electrical energy demand for the year 2000 is of the order of 778 GWh.

Hence a make up in the range of 349 to 549 GWh would have to be derived from an imported source of energy.

Three alternatives are available:

i) fuel oil, which is likely to become more expensive as competition increases for the remaining reserves - existing diesel power stations provide 270 GWh;

ii) nuclear energy, which developed countries are reluctant to see installed by developing countries;

iii) coal, which will remain abundant for the forseeable future.

Hence it appears probable that CEB would have to invest in a coal fired station at some time in the future. Comparison of the three alternatives proposed for year round power generators shows that the cost of production of electrical energy from bagasse pellets is less than from coal. The difference could be regarded as the real opportunity cost of bagasse.

11.04 When comparing the cost of production of Options A and C it is concluded that the latter alternative should be adopted because of the lower cost of production (Rs0.441 v/s Rs0.539/kWh) for a slightly lower energy output (182 v/s 229 GWh annually). The energy output of C is 79% of A whereas its production cost is 75% of A; if a turbo-alternator operates in a Group VI F.U.E.L., the energy ratio is 85%.

In Option C it was assumed that the cost of sugar factory equipment should not be added to the capital cost of the investment, because it had already been purchased for producing sugar. This affected favourably the cost of production of Option C.

Phasing of development

11.05 Since diesel alternators are likely to be phased out over the next fifteen years, it is logical to commence planning and development of steam-driven power plant capability immediately.

Assuming that the power station capacity should equal the day demand the installed condensing capacities should be as follows:

Year	Installed condensing capacity : MW
1985	61
1990	74
1995	90
2000	109

Projects

11.06 The following investigations need to be carried out:

a) feasibility and pilot plant studies of bagasse pelleting;

b) feasibility studies of a coal-fired, and of a coal and bagasse pellet fired, central power station of at least 30 MW output;

c) feasibility and design studies of modification of Medine's 10 MW turbo-alternator to accept pellets;

d) feasibility study of F.U.E.L.'s 20 MW Group VI turbo-alternator; and

e) feasibility studies of other sugar factory projects for Group V or Group VI power stations.

11.07 Studies of bagasse pelleting These studies are critical to the year round generation of sugar from bagasse. They would probably consist of the following stages:

a) evaluation of the first year's operation of the Hawaii Woodex plant;

b) examination of the Woodex process and evaluation of any possible improvements;

c) reassessment of other methods of drying, storing and transporting bagasse; and

d) pilot plant trials in Mauritius.

The cost of the feasibility study described in a) - c) above would be approximately Rs646 000 M ($63 000) plus expenses, based on an estimated 10 man-months charged current at UN rates.

11.08 Other studies These are currently being carried out at a French firm of consultants, Trans Energ and by WEAL Group.

Coordination

11.09 A Central Energy Planning Committee should be set up with powers to develop and enforce a national energy policy. It would be responsible to the Authority at ministerial level to develop national exploitation of sugarcane by-products. Its members would be representatives of the interested ministries, CEB, the gasoline companies, and the sugar producers. In the field of electrical energy it would develop long term plans to ensure that supply is available to meet demand, and that the necessary studies and pilot plant trials are carried on. In the short term it would regulate relationships between the parties (in conjunction with the Cane Millers and Planters Arbitration and Control Board), and would allocate responsibilities for individual developments.

END TABLES

Mauritius: Performance figures of the sugar industry, 1971-80

End Table 1

Year	Weight of cane crushed (t)	Fibre % cane	Fibre % bagasse	Sucrose % bagasse	Moisture % bagasse	Mixed juice % cane	Brix clarified juice	Brix syrup	Number of crushing days	Number of crushing hours per day	Total number of crushing hours
1971 a/	5 255 360	13.20	48.1	2.12	49.1	101.3	14.15	60.6	111	20.39	2 263
1972	6 314 668	12.86	48.4	1.94	49.0	100.6	13.28	59.4	132	20.20	2 667
1973	6 242 365	13.27	48.3	1.97	49.0	101.4	13.91	61.3	129	20.32	2 621
1974	5 963 655	12.77	48.2	1.99	49.1	100.9	13.98	62.0	126	20.22	2 548
1975 b/	4 316 027	13.97	47.8	1.98	49.5	101.3	13.13	59.6	118	16.78	1 980
1976	6 402 140	13.15	48.1	1.88	49.4	100.4	13.23	60.2	144	19.05	2 743
1977	6 022 198	13.68	47.7	1.98	49.7	100.5	13.38	61.4	137	19.27	2 640
1978	6 260 473	13.78	47.8	1.89	49.7	99.1	13.22	60.7	137	19.50	2 672
1979	6 313 084	13.86	47.8	1.96	49.6	98.3	13.75	61.7	136	19.95	2 713
1980 c/	4 564 356	14.70	47.6	1.91	49.8	98.8	12.81	61.7	104	19.41	2 019
Average	5 765 427	13.48	48.0	1.96	49.4	100.2	13.48	60.8	127	19.59	2 488
Averages excluding 1971,75,80	6 216 932	13.34	48.0	1.94	49.4	100.2	13.54	61.0	134	19.84	2 602

a/ 1971 crop was affected by severe drought.
b/ 1975 crop was affected by cyclone Gervaise.
c/ 1980 crop was affected by cyclone Claudette.

Source: MSIRI annual reports.

Mauritius: crushing rates of the sugar factories (tc/hr)

End Table 2

Factory	Year 1971 a/	1972	1973	1974	1975 b/	1976	1977	1978	1979	1980 c/	Nominal capacity
F.U.E.L.	245	250	248	247	219	234	220	246	234	226	240
Medine	163	162	173	166	141	161	163	168	170	164	170
Beau Champ	149	151	160	151	143	157	157	163	166	154	160
Mon Desert Alma	135	136	141	141	128	141	146	147	141	135	140
Mon Loisir	123	128	127	118	115	124	123	135	126	123	125
Belle Vue	115	119	125	122	109	116	109	117	123	128	125
Riche-en-Eau	111	115	113	111	107	121	116	123	119	114	120
Savannah	112	109	110	109	110	107	102	100	107	106	110
Constance	102	110	115	107	108	113	108	109	109	100	110
Union St Aubin	106	111	110	110	103	104	107	107	106	105	110
Mon Tresor	98	102	107	106	95	104	102	103	102	98	100
Highlands	94	98	97	98	91	98	98	94	96	96	100
Saint Antoine	99	105	106	104	102	107	104	105	96	96	100
Rose Belle	92	92	93	95	88	94	93	91	92	91	90
Britannia	77	80	79	80	78	87	86	85	87	86	90
Beau Plan	79	88	87	89	81	88	88	85	85	80	90
Reufac	96	100	100	97	89	92	84	81	79	79	80
The Mount	80	88	87	86	83	83	82	82	85	78	80
Solitude	80	87	84	86	77	85	85	82	82	77	80
Bel Ombre	67	71	70	65	65	67	63	66	71	66	70
Saint Felix	57	58	57	57	54	55	55	54	56	54	60
Total crushing capacity of Mauritius	2 280	2 360	2 389	2 345	2 180	2 338	2 291	2 343	2 332	2 256	2 350

a/ 1971 crop was affected by severe drought.
b/ 1975 crop was affected by cyclone Gervaise.
c/ 1980 crop was affected by cyclone Claudette.

Mauritius: steam production and type of process utilised in sugar factories

End Table 3

Factory	Nominal capacity tc/hr	Boiler house capacity; installed t steam/h at: 31 bar A	25-18 bar A	Less than 11 bar A	Mode of evaporation quadruple or quintuple effect	Vapour utilised for vacuum pans	Vapour bleeding utilised for juice heating	Remarks
F.U.E.L.	240	-	130	-	Quin	Vap I	Vap I	White sugar refinery
Medine	170	50 a/	70	-	Quad	Vap I	Vap I	Distillery
Beau Champ	160	-	130	-	Quad	Vap I, Ex	Vap I,II	White sugar refinery
Mon Desert Alma	140	50 a/	50	-	Quad	Vap I	Vap I,II	
Mon Loisir	125	-	68	-	Quin	Vap I	Vap I,II,III	
Belle Vue	125	-	120	-	Quin	Vap I	Vap I,II,III	White sugar refinery
Riche-en-Eau	120	-	30	30	Quad	Ex steam	Vap I,II	
Savannah	110	70 a/	-	-	Quad	Vap I	Vap I,II,III	
Constance	110	-	50	-	Quad	Ex	Vap I,II	
Union St Aubin	110	70 a/	-	-	Quin	Vap I	Vap I,II	
Mon Tresor	100	70 a/	-	-	Quad	Ex steam	Vap I	
Highlands	100	-	30	25	Quad	Ex steam	Vap I,II	
Saint Antoine	100	-	75	-	Quad	Vap I	Vap I,II	White sugar refinery and distillery
Rose Belle	90	-	50	20	Quad	Vap I, Ex	Vap I,II	
Britannia	90	-	60	30	Quad	Ex	Vap I,II	
Beau Plan	90	-	-	35	Quad	Vap I	Vap I,II	Distillery
Reufac	80	-	-	48	Quad	Ex	Vap I,II	
The Mount	80	-	-	50	Quad	Vap I	Vap I,II	
Solitude	80	-	20	25	Quad	Vap I, Ex	Vap I,II	
Bel Ombre	70	-	-	35	Quad	Ex steam	Vap I,II	
Saint Felix	60	-	-	32	Quin	Vap I, Ex	Vap I,II	

a/ Mon Desert, Savannah, Union St Aubin and Mon Tresor have limited the output pressure of their 31 bar A boilers to 21 bar A in order to suit their existing prime movers.
Medine utilises its 31 bar A boiler to operate a condensing turbo-alternator. The factory operates with 21 bar A steam only.

Mauritius: annual production of electrical energy from the sugar factories, 1975-80 (kWh) End Table 4

Factory	1975 a/	1976	1977	1978	1979	1980 b/
F.U.E.L.	5 301 000	8 214 000	6 583 000	6 949 000	6 229 000	3 724 000
Medine	2 071 300	2 187 300	2 015 800	1 260 700	1 203 500	10 215 000 c/
Beau Champ	1 776 840	2 446 680	2 483 420	2 037 840	2 263 190	2 020 150
Mon Desert Alma	1 111 200	2 704 800	2 577 600	2 449 200	3 129 600	1 267 800
Mon Loisir	643 900	1 005 700	1 502 500	1 923 700	2 316 400	1 783 500
Belle Vue	70 000	1 137 000	1 397 000	934 00	876 000	915 000
Riche-en-Eau	698 310	682 500	568 050	734 350	866 500	670 600
Savannah	1 496 500	2 010 600	1 949 700	2 188 100	2 087 500	1 338 000
Constance	1 952 000	2 961 750	2 310 500	2 867 500	2 722 500	1 691 500
Union St Aubin	-	-	-	349 680	506 640	626 401
Mon Tresor	-	-	-	-	-	264 000
Highlands	-	-	-	-	-	-
Saint Antoine	478 000	841 100	545 800	616 300	721 400	830 500
Rose Belle	4 000	4 000	54 720	800	13 760	-
Britannia	282 200	218 820	871 280	944 810	1 137 010	1 700
Beau Plan	724 400	790 700	1 376 500	1 508 400	1 562 700	1 141 000
Reufac	-	-	-	-	-	-
The Mount	26 700	104 200	181 700	153 200	600	36 600
Solitude	-	-	400	-	-	169 500
Bel Ombre	-	-	-	-	-	-
Saint Felix	-	-	-	-	-	-
Total	16 636 350	25 309 150	24 417 970	249 917 580	25 636 400	26 695 251

a/ 1975 crop was affected by cyclone Gervaise.
b/ 1980 crop was affected by cyclone Claudette.
c/ The only major addition to electricity production of the sugar industry was a pass-out/condensing turbo-alternator installed by Medine in 1980.

Energy distribution of typical turbine installations

End Table 5

Case	1	2	3	4	5	6	7	8	9	10
1. Inlet steam conditions	21 bar A at 350°C			31 bar A at 400°C			46 bar A at 440°C			71 bar A at 500°C
2. Exhaust pressure	2 bar A		0.10 bar A	2 bar A		0.10 bar A	2 bar A		0.10 bar A	0.05 bar A
3. Back pressure/condensing type	BP	BP	Cond	BP	BP	Cond	BP	BP	Cond	Cond
4. Internal efficiency of turbine	0.55	0.80	0.80	0.80	0.55	0.80	0.55	0.80	0.80	0.80
5. Energy input in fuel	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
6. Energy lost in flue gases	16.00	16.00	16.00	16.00	16.00	16.00	16.00	60.00	16.00	16.00
7. Energy going to exhaust	75.14	71.11	62.52	73.65	68.94	60.97	72.26	66.94	59.46	56.50
8. Energy output at turbine shaft	8.87	12.89	21.48	10.35	15.07	23.02	11.75	17.07	24.54	27.50
9. Electrical/mechanical output of machines	8.43	12.25	20.41	9.83	14.32	21.87	11.16	16.22	23.31	26.13
10. Energy consumed by auxiliaries	0.40	0.40	2.00	0.40	0.40	2.00	0.40	0.40	2.00	2.00
11. Net energy output of machine	8.03	11.85	18.41	9.43	13.92	19.87	10.76	15.82	21.31	24.13
Ratio: $\frac{\text{energy at turbine shaft } 8}{\text{energy going to exhaust } 7}$	0.118	0.181	0.344	0.141	0.219	0.378	0.163	0.255	0.413	0.487

See Annex 1 for calculations

APPENDIX 7A

Electrical energy obtainable from condensing turbo-alternators utilising one tonne of bagasse under various conditions — End Table 6

Case		1	2	3	4
Steam conditions		21 bar A at 350°C	31 bar A at 400°C	46 bar A at 440°C	71 bar A at 500°C
Boiler efficiency		0.78	0.82	0.84	0.84
Vacuum		0.10 bar A	0.10 bar A	0.10 bar A	0.05 bar A
Internal efficiency of turbo-alternator		0.80	0.80	0.80	0.80
Net energy content per 1 000 kg bagasse	kJ	7.641×10^6	7.641×10^6	7.641×10^6	7.641×10^6
Energy input to the steam	kJ	5.960×10^6	6.266×10^6	6.418×10^6	6.418×10^6
Energy output at the turbine shaft (=0.80)	kJ	1.524×10^6	1.718×10^6	1.875×10^6	2.101×10^6
Electrical output of alternator (x 0.95)	kJ	1.448×10^6	1.632×10^6	1.781×10^6	1.996×10^6
Energy consumption of auxiliaries	kJ	0.153×10^6	0.153×10^6	0.153×10^6	0.153×10^6
Net electrical output of station	kJ	1.295×10^6	1.479×10^6	1.628×10^6	1.843×10^6
	kWh	359	411	452	512
Factory group		II, III, IV	V	VI	CEB power station

Energy balances of five typical factories based on 100 tc/hr

End Table 7

Factory group		II	III	IV	V	VI
Process heat demand (Annexes 2,3,4)	kJ	104.890×10^6	91.647×10^6	80.573×10^6	80.573×10^6	80.573×10^6
<u>1 200 kW turbo-alternator:</u>						
Energy at turbine shaft (1 200 x $\frac{3\ 600}{0.95}$)	kJ	4.547×10^6	4.547×10^6	4.547×10^6	4.547×10^6	4.547×10^6
Internal efficiency of turbine	%	80	80	80	80	80
Energy going to process	kJ	25.122×10^6	25.122×10^6	25.122×10^6	20.763×10^6	17.831×10^6
<u>1 600 kW prime movers</u>						
Energy at turbine shaft (1 600 x $\frac{3\ 600}{0.95}$)	kJ	6.063×10^6	6.063×10^6	6.063×10^6	6.063×10^6	6.063×10^6
Internal efficiency of turbine	%	55	55	55	80	80
Energy going to process	kJ	51.381×10^6	51.381×10^6	51.381×10^6	27.685×10^6	23.776×10^6
Make up of process heat required	kJ	28.387×10^6	15.144×10^6	4.070×10^6	32.125×10^6	38.966×10^6
Energy output of back pressure turbine (mu=0.80 a/) exhausting the above make up energy	kJ	5.138×10^6	2.741×10^6	0.737×10^6	7.035×10^6	9.936×10^6
Electrical energy produced (x $\frac{0.95}{3\ 600}$)	kWh	1 357	723	194	1 856	2 622
Energy utilised by miscellaneous demand	kJ	18.192×10^6	18.192×10^6	18.192×10^6	18.756×10^6	19.170×10^6
Energy input in live steam	kJ	138.830×10^6	123.190×10^6	110.112×10^6	116.974×10^6	120.289×10^6
Efficiency of boiler based on NCV	%	78	78	78	82	84
Energy supplied by fuel	kJ	177.987×10^6	157.936×10^6	141.169×10^6	142.651×10^6	143.201×10^6
Weight of bagasse utilised (NCV=7 641 kJ/kg) b/	kg	23 294	20 670	18 475	18 669	18 741
Weight of bagasse available	kg	25 313	25 313	25 313	25 313	25 313
Surplus of bagasse left	kg	2 019	4 643	6 838	6 644	6 572

a/ mu = efficiency of turbine.
b/ weight of bagasse utilised is 90% of total bagasse available.

Amounts of pellets obtainable from 100 tc/hr Group IV, V and VI factories (100 t of cane basis) End Table 8

Factory group		IV	V	VI
Net energy supplies to boiler in fuel (see End Table 7)	kJ	141.169×10^6	142.651×10^6	143.201×10^6
Net calorific value of 35% moist bagasse	kJ/kg	10 686	10 686	10 686
Weight of 35% moist bagasse utilised	kg	13 211	13 349	13 401
Weight of 50% moist bagasse from mills	kg	25 313	25 313	25 313
Weight of 35% moist bagasse obtained from above $(25\ 313 \times \frac{0.769}{1.000})$	kg	19 466	19 466	19 466
Surplus of 35% moist bagasse left	kg	6 255	6 117	6 065
Amount of pellets obtainable from above $\frac{0.556}{0.769}$	kg	4 522	4 423	4 385

Electrical energy obtainable from condensing turbo-alternators utilising steam derived from one tonne bagasse pellets in different factory groups and a CEB power station

End Table 9

Condition of utilisation		Group II, III, IV factory	Group V factory	Group VI factory	CEB's power station
Live steam conditions		21 Bar A at 350°C	31 bar A at 400°C	46 bar A at 440°C	71 bar A at 500°C
Boiler efficiency		0.78	0.82	0.84	0.84
Vacuum		0.10 bar A	0.10 bar A	0.10 bar A	0.05 bar A
Internal efficiency of turbine		0.80	0.80	0.80	0.80
Net calorific value of bagasse	kJ/kg	7 641	7 641	7 641	7 641
Net calorific value of pellets	kJ/kg	15 763	15 763	15 763	15 763
Net electrical output of power station utilising 1 000 kg of 50% moist bagasse (see End Table 6)	kWh	359	411	452	512
Therefore net electrical output of power station utilising 1 000 kg of 10% moist pellets $\times \frac{15\ 763}{7\ 641}$	kWh	741	848	932	1 056

APPENDIX 7A

End Table 10

Opportunity costs of pellets and bagasse utilised under three different types of factory conditions, with respect to fuel oil used by CEB's diesel sets

Factory group		Group IV		Group V		Group VI	
Fuel		Pellets	Bagasse	Pellets	Bagasse	Pellets	Bagasse
1. Net calorific value of fuel	kJ/kg	15 763	7 641	15 763	7 641	15 763	7 641
2. Cost of fuel oil/kWh (Diesel)	Rs	0.739	0.739	0.739	0.739	0.739	0.739
3. Energy input in fuel - see End Table 6	kJ	7.641×10^6	7.641×10^6	7.641×10^6	7.641×10^6	7.641×10^6	7.641×10^6
4. Electric energy output - see End Table 6	kWh	359	359	411	411	452	452
5. Equivalent fuel oil cost (4 x 2)	Rs	265.30	265.30	303.73	303.73	334.03	334.03
6. Weight of fuel utilised (3 ÷ 1)	kg	484.74	1 000.00	484.74	1 000.00	484.74	1 000.00
7. Equivalent cost of fuel per ton (5 ÷ 6)	Rs/t	547.30	265.30	626.58	303.73	702.03	334.03
8. Deduct cost of transport to site a/	Rs/t	26.64	53.28	26.64	53.28	26.64	53.28
Opportunity cost of fuel	Rs/t	520.66	212.02	599.74	249.45	675.39	280.75

a/ Distance of factory from regional centre = 16.5 km (10 m)
Cost of transport of pellets or sugar = Rs 1.61/t/km one way (Rs2.58/t/m).
Normally bagasse would not be transported to another site; in case it is, the cost of transport is assumed to be twice that for transport of pellets.

Opportunity cost of bagasse pellets if used in place of coal at CEB's central power station

End Table 11

Fuel		Coal	Pellets
1. Net calorific value of fuel	kJ/kg	27 000	15 763
2. Price of coal at site Port Louis	Rs/t	622	-
3. Energy input in fuel - see Table 6	kJ	7.641×10^6	7.641×10^6
4. Electrical energy output - see Table 6	kWh	512	512
5. Weight of fuel utilised (line 3 ÷ 1)	kg	283.00	484.74
6. Equivalent cost of coal (line 2 x 5)	Rs	176.03	176.03
7. Equivalent cost of fuel (line 6 ÷ 5)	Rs/t	622	363.14
8. Deduct transport cost to site	Rs/t	Nil	53.28
Opportunity cost of fuel (7 - 8)	Rs/t	622	309.86
Cost of coal per kWh produced	Rs	0.344	-

APPENDIX 7A

Factory	Crushing Capacity tc/hr	Required heating surfaces v/s existing heating surfaces	Evaporator vessels 1 + clear juice pre-heaters m^2	2 m^2	3 m^2	4 m^2	5 m^2	Mixed juice heaters total heating surfaces m^2	Suggestions	Estimated cost Rs '000
F.U.E.L.	240	Required	2 611	1 207	1 126	1 066	547	955	No additional investment required	-
		Existing	2 752	1 000	1 000	1 000	1 226	1 118		
Medine	170	Required	1 850	855	797	755	388	677	Add: 5th effect 500 m^2 H.S.	870
		Existing	2 081	929	929	929	-	841		
Beau Champ	160	Required	1 740	805	750	710	365	637	Add: 5th effect 500 m^2 H.S.	870
		Existing	2 137	1 152	576	576	-	626		
Mon Desert Alma	140	Required	1 523	704	657	622	319	557	Add: cl juice heater 300 m^2 H.S.	700
		Existing	(1 300+929	650	650	650	-	751	Reshuffle evaporator vessels	-
Mon Loisir	125	Required	1 360	629	586	555	285	498	No additional investment required	-
		Existing	1 394	929	929	743	743	799		
Belle Vue	125	Required	1 360	629	586	555	285	498	No additional investment required	-
		Existing	1 858	1 000	766	766	766	744		
Riche-en-Eau	120	Required	1 360	604	563	533	274	478	Add: 1st effect 500 m^2 H.S.	870
		Existing	836	836	743	743	-	520	5th effect 300 m^2 H.S.	520
Savannah	110	Required	1 196	553	516	488	251	438	Add: 5th effect 300 m^2 H.S.	520
		Existing	1 514	750	750	750	-	694		
Constance	110	Required	1 196	553	516	488	251	438	Add: Cl. juice heater 200 m^2 H.S.	470
		Existing	1 022	836	743	743	-	640	5th effect 300 m^2 H.S.	520
Union St Aubin	110	Required	1 196	553	516	488	251	438	No additional investment required	-
		Existing	1 191	581	581	581	581	517		
Mon Tresor	100	Required	1 088	503	469	444	228	398	Add: 1st effect 500 m^2 H.S.	870
		Existing	697	697	697	697	-	557	5th effect 300 m^2 H.S.	520
Highlands	100	Required	1 088	503	469	444	228	398	Add: 1st effect 600 m^2 H.S.	1 050
		Existing	673	441	418	418	-	418	5th effect 300 m^2 H.S.	520
Saint Antoine	100	Required	1 088	503	469	444	228	398	Add: 2nd effect 500 m^2 H.S.	870
		Existing	1 161	465	465	465	-	581		
Rose Belle	90	Required	979	453	422	400	205	358	Add: Cl. juice heater 150 m^2 H.S.	350
		Existing	836	567	576	576	-	-	5th effect 300 m^2 H.S.	520
Britannia	90	Required	979	453	422	400	205	358	Add: 1st effect 500 m^2 H.S.	870
		Existing	571	472	418	418	-	502	5th effect 300 m^2 H.S.	520
									Sub-total	11 430

APPENDIX 7A

Capital investments required for implementing Step 1 (cont)

Factory	Crushing Capacity tc/hr	Required heating surfaces v/s existing heating surfaces	Evaporator vessels 1 + clear juice pre-heaters m^2	2 m^2	3 m^2	4 m^2	5 m^2	Mixed juice heaters total heating surfaces m^2	Suggestions	Estimated cost Rs '000
Beau Plan	90	Required	979	453	422	400	205	358	Add: Cl. juice heater 200 m^2 H.S.	470
		Existing	836	496	496	557	-	503	5th effect 300 m^2 H.S.	520
Reufac	80	Required	870	402	375	355	182	318	Add: 1st effect 300 m^2 H.S.	520
		Existing	581	581	581	581	-	432	5th effect 250 m^2 H.S.	440
Mount	80	Required	870	402	375	355	182	318	Add: 5th effect 250 m^2 H.S.	440
		Existing	1 022	441	441	441	-	496		
Solitude	80	Required	870	402	375	355	182	318	No additional equipment required	-
		Existing	743+418	418	418	418	-	952	Reshuffle heaters and vessels	
Bel Ombre	70	Required	762	352	328	311	160	279	Add: 1st effect 400 m^2 H.S.	700
		Existing	348	348	348	348	-	380	5th effect 200 m^2 H.S.	350
Saint Felix	60	Required	653	302	281	266	137	239	No additional equipment required	-
		Existing	774	446	321	321	321	248		
									Total	14 870

Capital investment required for implementing Step 2 — End Table 13

Group IV factories	Crushing rate of factory tc/hr	Weight of pellets obtainable annually t	Estimated cost of pelleting plants Rs'000
F.U.E.L.	240	28 868	29 000
Medine	170	20 448	23 000
Beau Champ	160	19 246	23 000
Mon Desert Alma	140	16 840	23 000
Mon Loisir	125	15 036	23 000
Belle Vue	125	15 036	23 000
Riche-en-Eau	120	14 434	23 000
Savannah	110	13 231	17 500
Constance	110	13 231	17 500
Union St Aubin	110	13 231	17 500
Mon Tresor	100	12 029	17 500
Highlands	100	12 029	17 500
Saint Antoine	100	12 029	17 500
Rose Belle	90	10 826	17 500
Britannia	90	10 826	17 500
Total	1 890	227 340	307 000

Note: Total weight of pellets produced: 227 340 t Total electrical energy produced: 229.364 GWh Purchase price of bagasse: Nil	Total cost of production per year Rs '000	Unit cost of production Rs/t	Rs/kWh
Step 1: Modification of process department: (Capital cost Rs11.4 M)			
Depreciation: 4%	460	2.023	0.002
Interest on capital: 10%	1 140	5.015	0.005
Maintenance: 2%	220	0.967	0.001
Insurance: 1%	110	0.484	0.001
Sub-total	1 930	8.489	0.009
Step 2: Production of bagasse pellets: (Capital cost Rs307 M)			
Depreciation: 4%	12 280	54.016	0.053
Interest on capital: 10%	30 700	135.040	0.134
Maintenance: 2%	6 140	27.000	0.027
Insurance: 1%	3 070	13.500	0.013
Labour: 15 Woodex plants x 2 operators/shift x 2 shifts x Rs25 000/operator/yr	1 500	6.598	0.007
Electricity: This item has been deducted from total electrical energy output	-	-	-
Transport to Port Louis: Rs53/t of pellets	12 050	53.000	0.053
Sub-total	65 740	289.154	0.287
Step 3 Option A: Production of electricity through Central Power Station (Capital cost Rs350 M) a/			
Depreciation: 4%	14 000	61.582	0.061
Interest on capital: 10%	35 000	153.954	0.153
Maintenance: 2%	7 000	30.791	0.030
Insurance: 1%	3 500	15.395	0.015
Labour and supervisory charges: b/	1 000	4.399	0.005
Electricity: This item is included in the overall efficiency of the Power Station	-	-	-
Sub-total	60 500	266.121	0.264
Grand Total	128 170	563.764	0.56

a/ A 30 MW coal fired power station installed at Port Louis would cost some Rs460 M ($44.9 M). Out of this some Rs110 M ($10.7) would be devoted to unloading facilities for colliers. Hence the capital cost of the power station proper is taken as Rs350 M ($34.2) in the cost of production calculations.

b/ 10 operators/12 hr shift ie 20 operators earning Rs25 000 annually; 3 supervisors earning Rs100 000 annually and 3 assistant supervisors earning Rs60 000 annually.

Cost of production of electrical energy, Option B

End Table 15

Note: Total weight of pellets produced: 227 340 t Total electrical energy produced: 201.174 GWh Purchase price of bagasse: Nil	Total cost of production per year Rs '000	Unit cost of production Rs/t	Rs/kWh
Step 1: Modification of process department: (Capital cost Rs11.4 M)			
Depreciation: 4%	460	2.023	0.002
Interest on capital: 10%	1 140	5.015	0.006
Maintenance: 2%	220	0.967	0.001
Insurance: 1%	110	0.484	0.001
Sub-total	1 930	8.489	0.010
Step 2: Production of bagasse pellets: (Capital cost Rs307 M)			
Depreciation: 4%	12 280	54.016	0.061
Interest on capital: 10%	30 700	135.040	0.153
Maintenance: 2%	6 140	27.000	0.031
Insurance: 1%	3 070	13.500	0.015
Labour: 15 plants x 2 operators/shift x 2 shifts x Rs25 000/operator/yr	1 500	6.598	0.008
Electricity: This item has been deducted from total electrical energy output	-	-	-
Transport to regional power station: Rs27/t of pellets	6 138	27.000	0.030
Sub-total	59 828	263.154	0.298
Step 3 Option B: Production of electricity through Regional Power Station (Capital cost Rs240 M) a/			
Depreciation: 4%	9 600	42.228	0.048
Interest on capital: 10%	24 000	105.569	0.119
Maintenance: 2%	4 800	21.114	0.024
Insurance: 1%	2 400	10.557	0.012
Labour and supervisory charges: b/	1 000	4.399	0.005
Electricity: This item is included in the overall efficiency of the Power Station	-	-	-
Sub-total	41 800	183.867	0.208
Grand Total	103 558	455.510	0.516

a/ Capital investment: a 10 MW power station of this type would comprise a 50 t/hr boiler and a condensing turbo-alternator. The estimated cost of such a power plant would be of the order of Rs80 M ($8 M) ie Rs240 M ($24 M) for three stations.

b/ Maintenance and operation of the boiler would be carried out by the regular factory staff. Provision is made for one extra supervisor at each station, plus 8 operators.

Condensing electrical energy produced and pellets consumed during the cropping season under Option C

End Table 16

Factory		Medine	Mon Desert	Savannah	Total
Crushing rate	tc/hr	170	170	110	-
Boiler capacity required	t/h	72.4	59.6	46.9	179
Boiler capacity installed	t/h	120	90	70	280
Extra boiler capacity available during crop	t/h	47.6	30.4	23.1	101
Condensing power obtainable from this extra boiler capacity during the crop	kW	9 262	5 916	4 495	19 673
Weight of pellets utilised by extra boiler capacity	t/h	10.924	6.977	5.301	23.202

Cost of production of electrical energy, Option C

End Table 17

Note: Total weight of pellets produced: 227 340 t Total electric energy produced: 182.017 GWh Purchase price of bagasse: Nil	Total cost of production per year Rs '000	Unit cost of production Rs/t	Rs/kWh
Step 1: Modification of process departments: (Capital cost Rs11.4 M)			
Depreciation: 4%	460	2.023	0.003
Interest on capital: 10%	1 140	5.015	0.006
Maintenance: 2%	220	0.967	0.001
Insurance: 1%	110	0.484	0.001
Sub-total	1 930	8.489	0.011
Step 2: Production of bagasse pellets: (Capital cost Rs307 M)			
Depreciation: 4%	12 280	54.016	0.067
Interest on capital: 10%	30 700	135.040	0.169
Maintenance: 2%	6 140	27.000	0.034
Insurance: 1%	3 070	13.500	0.017
Labour: 15 plants x 2 operators/shift x 2 shifts x Rs25 000/operator/yr	1 500	6.598	0.008
Electricity: This item has been deducted from total electric energy output	-	-	-
Transport to regional power station: Rs27/t of pellets	6 138	27.000	0.034
Sub-total	59 828	263.154	0.329
Step 3 Option C: Production of electricity through Group V factory power station (Capital cost Rs80 M) a/			
Depreciation: 4%	3 200	14.076	0.018
Interest on capital: 10%	8 000	35.190	0.044
Maintenance: 2%	1 600	7.038	0.009
Insurance: 1%	800	3.519	0.004
Labour and supervisory charges: Rs1.0 M	1 000	4.399	0.005
Electricity: This item is included in the overall efficiency of the power station	-	-	-
Sub-total	14 600	64.222	0.080
Grand Total	76 358	335.865	0.420

a/ Capital investment: Two 10 MW condensing turbo sets would cost approximately Rs80 M (80 M). The rest of the equipment is already in operation in the factories. Since the lives of boilers and turbo-alternators are not materially affected by operation for 320 or 134 d/y, no account is taken of the value of existing equipment.

Cost of production of electrical energy from coal

End Table 18

Note: Electrical energy produced: 229 364 GWh annually Weight of coal utilised: 126 777 t	Total cost of production per year Rs '000	Unit cost of production Rs/t	Unit cost of production Rs/kWh
Capital cost Rs460 M ($44.9 M)			
Cost of coal landed at site - Port George, Port Louis	78 855	622.000	0.344
Depreciation of equipment: 4%	18 400	145.137	0.080
Interest on capital: 10%	46 000	362.842	0.200
Maintenance: 2%	9 200	72.568	0.040
Insurance premium: 1%	4 600	36.284	0.020
Labour and supervision: Rs1 M annually	1 000	7.888	0.004
Internal consumption of electric energy: this item is included in the overall efficiency of the plant	-	-	-
Total	158 055	1 246.719	0.688

APPENDIX 7A

ANNEXES

Calculation of energy distribution different types of turbines operating under various conditions

Annex 1

Case		1	2	3	4	5	6	7	8	9	10
Live steam conditions		21 bar A at 350°C			31 bar at 400°C			46 bar A at 400°C			71 bar A at 500°C
Exhaust pressure		2 bar A		0.1 bar A	2 bar A		0.1 bar A	2 bar A		0.1 bar A	0.05 bar A
Internal efficiency of turbo		0.55	0.80	0.80	0.55	0.80	0.80	0.55	0.80	0.80	0.80
Enthalpy point 1	kJ/kg	3 137	3 137	3 137	3 231	3 231	3 231	3 300	3 300	3 300	3 409
Enthalpy point 2	kJ/kg	2 632	2 632	2 196	2 620	2 620	2 190	2 590	2 590	2 165	2 070
Isentropic drop	kJ/kg	505	505	941	611	611	1 041	710	710	1 135	1 339
Work done	kJ/kg	278	404	753	336	489	833	391	568	908	1 071
Enthalpy point 2	kJ/kg	2 859	2 733	2 384	2 895	2 742	2 398	2 909	2 732	2 392	2 338
Enthalpy condensate (at Ex p)	kJ/kg	505	505	192	505	505	192	505	505	192	138
Heat given to process	kJ/kg	2 354	2 228	2 192	2 390	2 237	2 206	2 404	2 227	2 200	2 200
Heat added by boiler	kJ/kg	2 632	2 632	2 945	2 726	2 726	3 039	2 795	2 795	3 108	3 271
Efficiency of boiler	kJ/kg	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Heat given by fuel	kJ/kg	3 133	3 133	3 506	3 245	3 245	3 618	3 327	3 327	3 700	3 894
<u>Percentage distribution</u>											
Heat given by fuel		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Work done		8.87	12.89	21.48	10.35	15.06	23.03	11.75	17.07	24.54	27.50
Heat given to process		75.13	71.11	62.52	73.65	68.94	60.97	72.26	66.94	59.46	56.50
Heat lost in flue gases		16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00

APPENDIX 7A

Process steam demand of a 100 tc/hr Level 1 factory

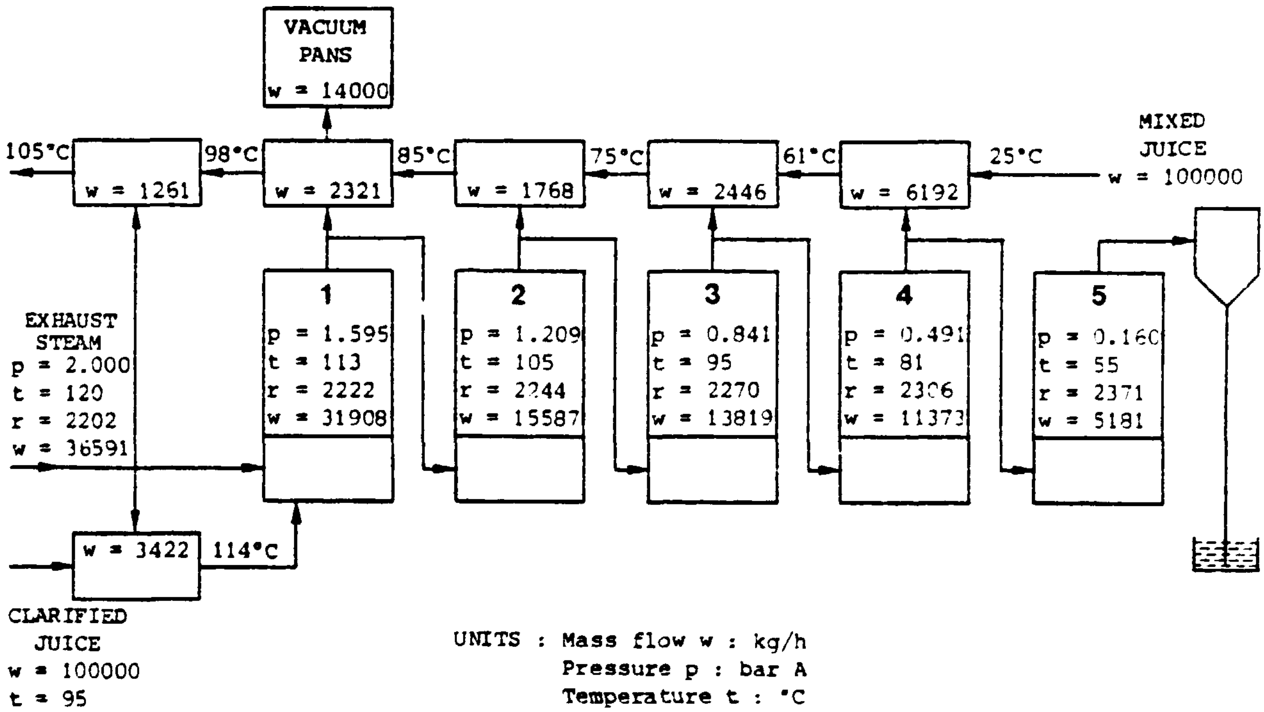
1. Process steam demand of a Level 1, 100 tc/hr factory using:

   a) quintuple effect evaporation;

   b) Vapour I bleeding for boiling;

   c) Vapour IV, III, II and I for juice heating is detailed below.

FIG. A2.1



UNITS : Mass flow w : kg/h
Pressure p : bar A
Temperature t : °C
Latent heat r : kJ/kg

2. The following assumptions have been made:

   a) 1 kg of vapour will evaporate 1 kg of water in next effect;

   b) specific heat of juice: 0.9 x 4.1868 = 3.768 kJ/kg°C;

c) amount of vapour used for boiling: 14% weight of cane;
d) heat loss in juice heaters: 5% of heat input;
e) pressure and temperature distribution in evaporator: as represented on diagram;
f) brix of juice at inlet of evaporator: 13.50
g) brix of syrup at exit of evaporator: 61.00

3. Consider a factory dealing with 100 000 kg juice per hour as shown in Fig A2.1.

Bleeding at 4th effect $P_4 = \frac{100\ 000 \times 3.768 \times (61-25)}{2\ 306 \times 0.95} = 6\ 192$ kg/hr

Bleeding at 3rd effect $P_3 = \frac{100\ 000 \times 3.768 \times (75-61)}{2\ 270 \times 0.95} = 2\ 446$ kg/hr

Bleeding at 2nd effect $P_2 = \frac{100\ 000 \times 3.768 \times (85-75)}{2\ 244 \times 0.95} = 1\ 768$ kg/hr

Bleeding at 1st effect $P_1 = \frac{100\ 000 \times 3.768 \times (98-85)}{2\ 222 \times 0.95} = 2\ 321$ kg/hr

+ vacuum pans demand = 14 000 kg/hr

$P_1 = 16\ 321$ kg/hr

Total evaporation $E = 100\ 000 \times \left(1 - \frac{13.50}{61.00}\right) = 77\ 869$ kg

Let x = amount of vapour going to condenser

Therefore $E = 5x + P_1 + 2P_2 + 3P_3 + 4P_4$

$77\ 869 = 5x + 16\ 321 + 2(1\ 768) + 3(2\ 446) + 4(6\ 192)$

Where x = 5 181 kg/hr

Evaporator steam demand $= x + P_1 + P_2 + P_3 + P_4$

= 31 908 kg/hr

Finishing heater steam demand $= \frac{100\ 000 \times 3.768 \times (105-98)}{2\ 202 \times 0.95}$

= 1 261 kg/hr

Clarified juice heater steam demand $= \frac{100\ 000 \times 3.768 \times (114-95)}{2\ 202 \times 0.95}$

= 3 422 kg/hr

Total process steam demand = 31 908 + 1 261 + 3 422

= 36 591 kg/hr

Process steam at 2 bar A saturated is fed to the evaporator where it condenses, and the condensates are returned to the boiler at condensing temperature. Heat liberated per kg of steam:

= latent heat @ 2 bar
= 2 202 kJ/kg

Therefore heat demand = $33\ 591 \times 2\ 202 = 80.573 \times 10^6$ kJ/hr.

Process steam demand of a 100 tc/hr Level 2 factory

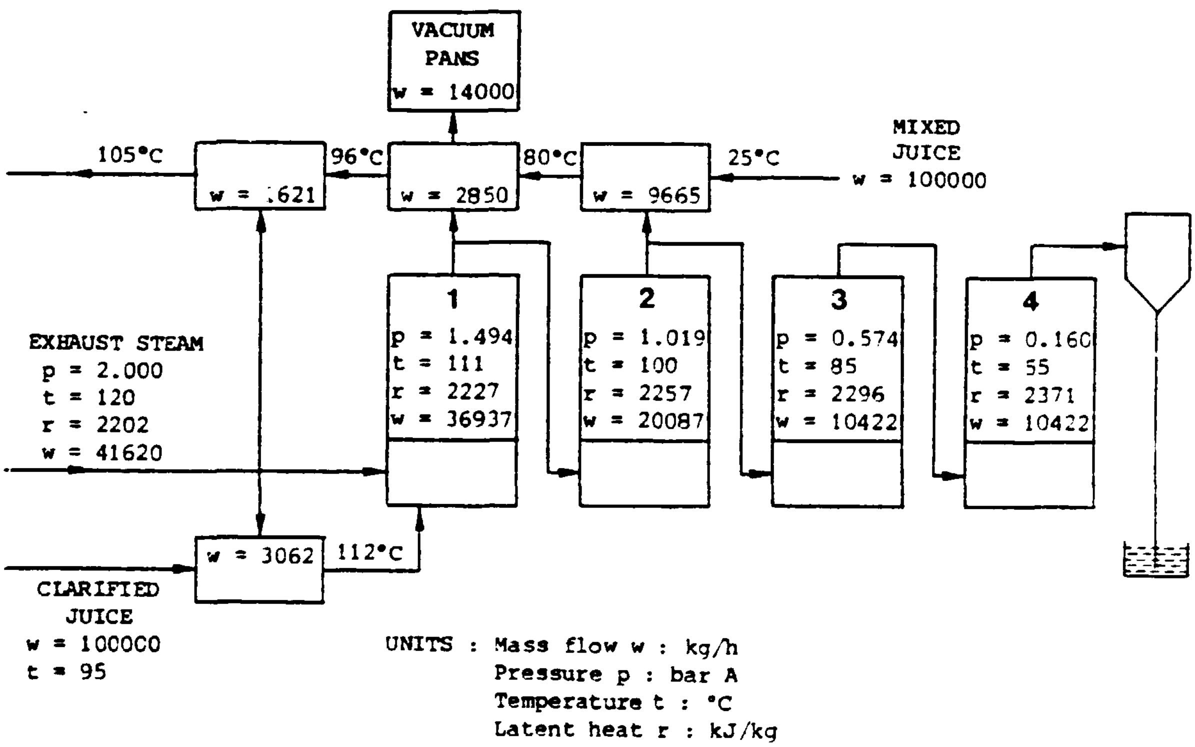
1. Details are provided of the process steam demand of a Level 2 100 tc/hr factory using:

a) quadruple effect evaporation;

b) Vapour I bleeding for boiling;

c) Vapour I and II bleeding for juice heating.

FIG.A3.1



2. The following assumptions have been made:

a) brix of juice at inlet of evaporator: 13.50°;
b) brix of syrup at exit of evaporator: 61.00°
c) pressure and temperature distribution in evaporator: as represented on diagram;
d) 1 kg of vapour will evaporate 1 kg of water in next effect;
e) amount of vapour used for boiling: 14% weight of cane;
f) specific heat of juice; 0.9 x 4.1868 = 3.768/kJ/kg°C;
g) heat loss in juice heaters: 5% of heat input.

3. Consider a factory dealing with 100 000 kg juice per hour as per layout in Fig a3.1.

Bleeding at 2nd effect $P_2 = \dfrac{100\ 000 \times 3.768 \times (80-25)}{2\ 257 \times 0.95} = 9\ 665$ kg/hr

Bleeding at 1st effect $P_1 = \dfrac{100\ 000 \times 3.768 \times (96-80)}{2\ 227 \times 0.95} = 2\ 850$ kg/hr

+ vacuum pans demand = 14 000 kg/hr

$P_1 = 16\ 850$ kg/hr

Total evaporation $E = 100\ 000 \times (1- \dfrac{13.50}{61.00}) = 77\ 869$ kg

Let y = amount of vapour going to condenser

Therefore $E = 4y + P_1 + 2P_2$

$77\ 869 = 5y + 16\ 850 + 2(9\ 665)$

Where $y = 10\ 422$ kg/hr

Evaporator steam demand $= y + P_1 + P_2 = 36\ 937$ kg/hr

Finishing heater steam demand $= \dfrac{100\ 000 \times 3.768 \times (105-96)}{2\ 202 \times 0.95}$

$= 1\ 621$ kg/hr

Clarified juice heater steam demand $= \dfrac{100\ 000 \times 3.768 \times (112-95)}{2\ 202 \times 0.95}$

Total process steam demand = 36 937 + 1 621 + 3 062 kg/hr

= 41 620 kg/hr

Latent heat of steam @ 2 bar A sat = 2 202 kJ/kg

Process heat demand $= 41\ 620 \times 2\ 202 = 91.647 \times 10^6$ kJ/hr

Annex 4

Process steam demand of a 100 tc/hr Level 3 factory

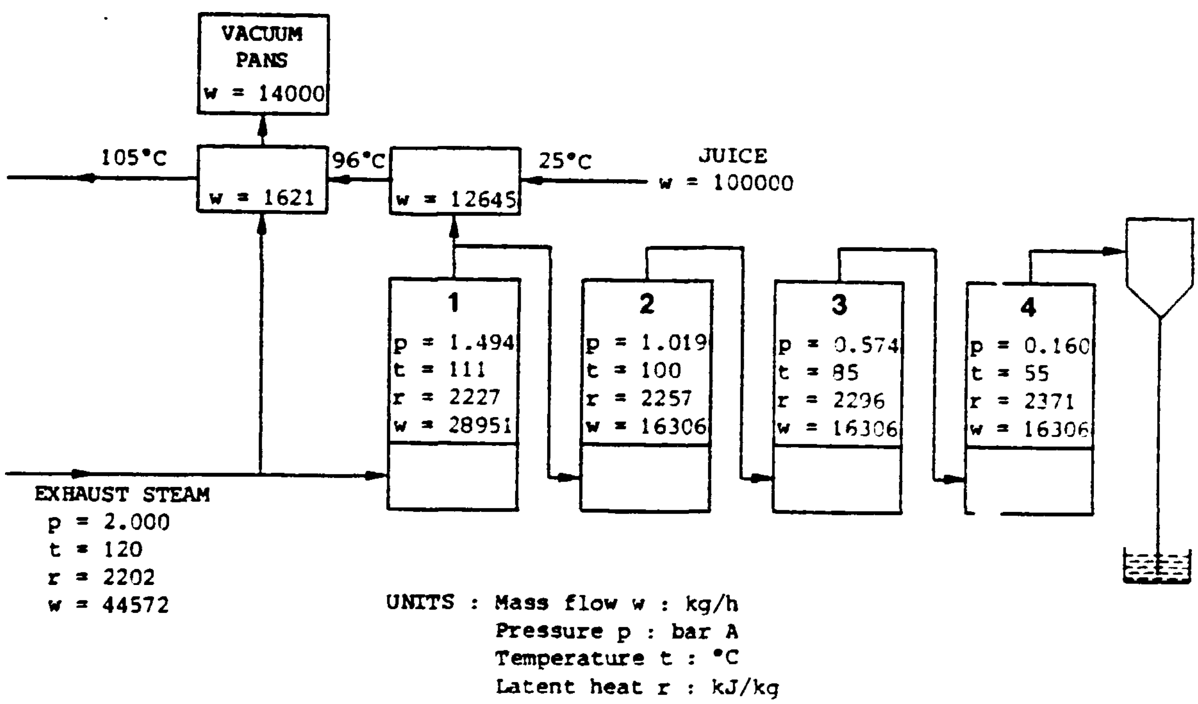
1. Details are provided of the process steam demand of a Level 3 100 tc/hr factory using:

a) quadruple effect evaporation;

b) Vapour I bleeding for juice heating;

c) Process steam for boiling.

FIG.4.1



2. The following assumptions have been made:

a) brix of juice at inlet of evaporator: 13.50°;
b) brix of syrup at exist of evaporator: 61.00°
c) pressure and temperature distribution in evaporator: as represented on Fig A4.1;

d) 1 kg of vapour will evaporate 1 kg of water in next effect;
e) amount of vapour used for boiling: 14% weight of cane;
f) specific heat of juice; 0.9 x 4.1868 = 3.768 kJ/kg°C;
g) heat loss in juice heaters: 5% of heat input.

3. Consider a factory dealing with 100 000 kg juice per hour as per layout in Fig A4.1.

Bleeding at 1st effect $P_1 = \frac{100\ 000 \times 3.768 \times (96-25)}{2\ 227 \times 0.95} = 12\ 645$ kg/hr

Total evaporation $E = 100\ 000 \times (1 - \frac{13.50}{61.00}) = 77\ 869$ kg

Let z = amount of vapour going to condenser

Therefore $E = 4z + P_1$

$77\ 869 = 4z + 12\ 645$

Where z = 16 306 kg/hr

Evaporator steam demand = $z + P_1$ = 28 951 kg/hr

Finishing heater steam demand = $\frac{100\ 000 \times 3.768 \times (105-96)}{2\ 202 \times 0.95}$

= 1 621 kg/hr

Clarified juice heater steam demand = $\frac{100\ 000 \times 3.768 \times (112-95)}{2\ 202 \times 0.95}$

= 3 062 kg/hr

Vacuum pans steam demand = 14 000 kg/hr

Total process steam demand = 28 951 + 1 621 + 3 062 + 14 000 kg/hr

= 47 634 kg/hr

Latent heat of steam @ 2 bar A sat = 2 202 kJ/kg

Process heat demand = 47 634 x 2 202 = 104.890×10^6 kJ/hr

Miscellaneous steam demands

Annex 5

The heat required to raise 6.0 t of water from 25°C to live steam conditions is shown below

Case	1	2	3
Live steam conditions:	21 bar A at 250°C	31 bar A at 400°C	46 bar A at 440°C
Enthalpy live steam:	3 137 kJ/kg	3 231 kJ/kg	3 300 kJ/kg
Enthalpy water at 25°C	105 kJ/kg	105 kJ/kg	105 kJ/kg
Heat input required	3 032 kJ/kg	3 126 kJ/kg	3 195 kJ/kg
Heat required to raise 6.0 t of steam per hour	18.192×10^6 kJ	18.756×10^6 kJ	19.170×10^6 kJ

Comparison of Woodex with bagasse at various moisture contents

Annex 6

Product		50% moist bagasse	35% moist bagasse	10% moist pellets
Percentage composition:				
Solid fraction (Fibre + Brix)	%	50	65	90
Moisture	%	50	35	10
Net calorific value of solid fraction	kJ/kg	17 794	17 794	17 794
Latent heat of moisture	kJ/kg	2 512	2 512	2 512
Product derived from 100 kg solids				
Latent heat of moisture	kJ/kg	2 512	2 512	2 512
Solid fraction	kg	100.000	100.000	100.000
Moisture	kg	100.000	53.846	11.111
Total weight of product	kg	200.000	153.846	111.111
Net energy content				
Net energy of solid fraction	kJ	17 794 x 100.000	17 794 x 100.000	17 794 x 100.000
-(Net energy loss due to moisture)	kJ	-(2 512 x 100.000)	-(2 512 x 53.846)	-(2 512 x 11.111)
Net energy content of product	kJ	1.528×10^6	1.644×10^6	1.751×10^6
Net calorific value of product	kJ/kg	7 641	10 686	15 763
Relative energy wrt 50% moist bagasse		1.000	1.076	1.146
Relative weight wrt 50% moist bagasse		1.000	0.769	0.556

Transport of bagasse pellets to a power station at Port Louis

Annex 7

Factory	tc/hr	Distance from Port Louis km	Wt of pellets obtainable: t	tonne-km'000	Remarks
<u>Case 1</u>:					
F.U.E.L	240	34	28 868	982	Case 1:
Medine	170	19	20 448	389	These factories represent the factories
Beau Champ	160	46	19 246	885	which should undergo Step 1.
Mon Desert Alma	140	14	16 840	236	(See Section 8 of text)
Mon Loisir	125	27	15 036	406	
Belle Vue	125	18	15 036	271	
Riche-en-Eau	120	45	14 434	650	
Savannah	110	48	13 231	635	
Constance	110	32	13 231	423	
Union St Aubin	110	48	13 231	635	
Mon Trésor	100	53	12 029	638	
Highlands	100	19	12 029	229	
St Antoine	100	26	12 029	313	
Rose Belle	90	34	10 826	368	
Britannia	90	42	10 826	455	
Total and Averages	1 890	33.1	227 340	7 515	
<u>Case 2</u>:					
Beau Champ	160	46	19 246	885	Case 2:
Mon Loisir	125	27	15 036	406	These factories represent the Group IV
Belle Vue	125	18	15 036	271	factories which would send their excess
Riche-en-Eau	120	45	14 434	650	of bagasse/pellets to an external power
Constance	110	32	13 231	423	station.
Highlands	100	19	12 029	229	<u>Conclusion</u>
St Antoine	100	26	12 029	313	1) The average distance from Port Louis
Rose Belle	90	34	10 826	368	is approximately the same as with
Britannia	90	42	10 826	455	Case 1. Therefore in all calculations
					the average distance from Port Louis will
					be taken as 33 km.
					2) If the bagasse/pellets is transported
					to a neighbouring factory, the average
					distance will be taken as 16.5 km.
Total and Averages	1 020	32.6	122 693	4 000	

3. **Brix balance**

Bx_0 x 100 000 = 13.50 x 100.000	Bx_0 = 13.50)	
		) hence b_1 = 16.67
= Bx_1 x (100 000-31 908)	hence Bx_1 = 19.83)	
		) hence b_2 = 22.77
= Bx_2 x (100 000-31 908-15 587)	hence Bx_2 = 25.71)	
		) hence b_3 = 30.31
= Bx_3 x (100 000-31 908-15 587-13 819)	hence Bx_3 = 34.90)	
		) hence b_4 = 42.17
= Bx_4 x (100 000-31 908-15 587-13 819-11 373)	hence Bx_4 = 42.17)	
		) hence b_5 = 55.21
= Bx_5 x (100 000-31-908-15 587-13 819-11 373-5 181)	hence Bx_5 = 55.21)	

4. **Determination of heating surfaces of evaporator effects**

Assume purity of juice = 85%
Length of evaporator tubes = 1 800 mm (ie hydrostatic head of boiling liquid = 30 mm)

Specific evaporation coefficient "C" by Dessin formula

"C" kg/m²h°C = 0.001 (100-b) (T-54)

where b = average brix of juice inside effect,
T = temp of heating vapour inside calandria (°C)

Effect		1	2	3	4	5
Elevation of boiling point:						
1) due to concentration of liquid	°C	0.2	0.4	0.7	1.4	2.7
2) due to hydrostatic head of liquid	°C	0.6	0.8	1.0	1.8	4.5
Total	°C	0.8	1.2	1.7	3.2	7.2
Temperature of vapour in effect T_V	°C	113	105	95	81	55
Temperature of boiling liquid T_L	°C	113.8	106.2	96.7	84.2	62.2
Temperature of vapour inside calandria	°C	120	113	105	95	81
T across heating surface	°C	6.2	6.8	8.3	10.8	18.8
Evaporation in effect: m	kg/hr	31 908	15 587	13 819	11 373	5 181
Average brix inside effect "b"	°Bx	16.67	22.77	30.31	42.17	55.21
Specific evaporation coef "c"	kg/m²h°C	5.50	4.56	3.55	2.37	1.21
Heating surface required "S"						
$S = \frac{m}{TxC}$	m²	935	503	469	444	228

Note: Ref: E Hugot: Handbook of Cane Sugar Engineering, 2nd Edition, p488 et seq.

APPENDIX 7A

5. Determination of heating surfaces of juice heaters

Assume velocity of juice inside tubes = 2 m/sec

Heat transfer coefficient "k" (k/Cal/m^2 °C h) = T(5+u)

T being temperature of the heating vapour
u being the velocity of juice inside tubes.

Hence "k" = 7T kCal/m^2 °C h = 29.3 T kJ/m^2 °C h.

Juice Heater		H_{CL}	H_E	H_1	H_2	H_3	H_4
Juice flow "m"	kg/hr	100 000	100 000	100 000	100 000	100 000	100 000
Specific heat of juice "C"	kJ/h°C	3.768	3.768	3.768	3.768	3.768	3.768
Temperature of heating vapour	T°C	120	120	113	105	95	81
Heat transfer coefficient "k"	kJ/m^2 °C h	3 516	3 516	3 311	3 077	2 783	2 373
Temperature of inlet juice	t_1°C	95	98	85	75	61	25
Temperature of outlet juice	t_2°C	114	105	98	85	75	61
"O Log" = (log$_e$ $\frac{T - t_1}{T - t_2}$		1.427	0.383	0.624	0.405	0.531	1.03
Heating surface req: $\frac{mc}{k}$ O Log	m^2	153	41	71	50	72	164

The clear juice heater heating surface is normally added to that of the calandria of the first effect.

Hence the heating surface of the first effect becomes 153+935 = 1 088 m^2

Heating surface of second effect = 503 m^2
Heating surface of third effect = 469 m^2
Heating surface of fourth effect = 444 m^2
Heating surface of fifth effect = 228 m^2
Total heating surface of mixed juice heaters = 398 m^2

Note: Ref: E Hugot: Handbook of Cane Sugar engineering, 2nd Edition, p424 et seq.

Heating surface requirements of a 100 tc/hr Level 1 factory

1. Details are provided of heating surfaces required for evaporator and juice heaters of a Level 1 100 tc/hr factory using:

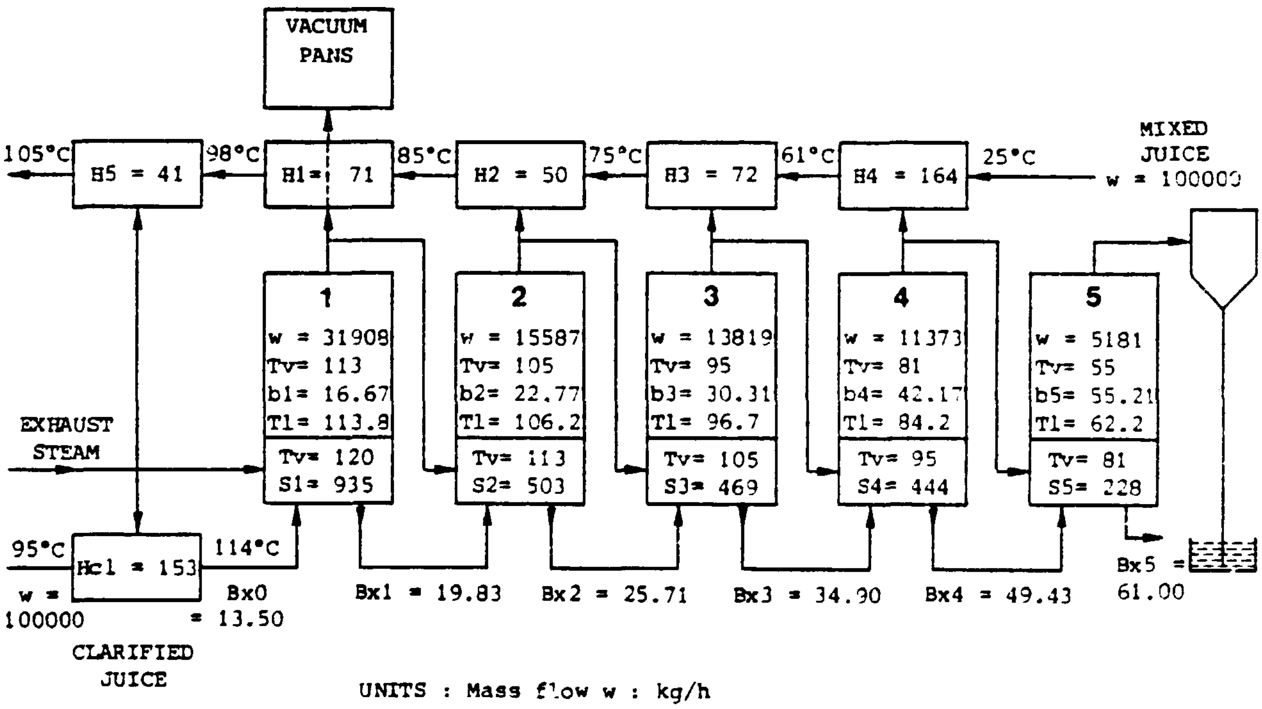
   a) quintuple effect evaporation;

   b) Vapour I bleeding for boiling;

   c) Vapour IV, III, II and I for juice heating as detailed below.

2. Mass flow and temperature distribution are as shown in Figure A8.1.

FIG. 8.1



UNITS : Mass flow w : kg/h
Temperature of liquid : Tl (°C)
Temperature of vapour : Tv (°C)
Brix after effect : Bxn
Average brix inside effect : bn
Heating surface of effect : Sn (m2)
Heating surface juice heater : Hn (m2)

Annex 9

Boiler capacity required by a 100 tc/hr Group IV factory

Process steam demand (Annex 2)	kg/hr	36 951
"Miscellaneous" demands (Annex 5)	kg/hr	6 000
Capacity of boiler required	kg/hr	42 591

Annex 10

Electrical energy output and pellet consumption for Option 'C'

Enthalpy live steam (31 bar A at 400°C)	kJ/kg	3 231
Enthalpy condensates (0.10 bar A)	kJ/kg	192
Energy input per kg of steam	kJ	3 039
Energy supplied by fuel) (÷ 0.84) per kg of steam produced)	kJ	3 618
NCV of bagasse pellets	kJ/kg	15 763
weight of pellets utilised per 1 000 kg steam (1 000 x 3 618 ÷ 15 763)	kg	229.5
Condensing electric energy output (End Table 9) $\frac{229.5}{1\ 000}$ x 848	kW	194.6

APPENDIX 7A

APPENDIX 7B

BY-PRODUCTS: ENERGY FROM BAGASSE - OTHER FORMS

CONTENTS

SUMMARY

1. Laboratory tests indicate that charcoal can be produced from bagasse, though it is understood that no industrial scale plants are operating at the present time.

2. It is proposed that the possibility of using various types of carbonisation plant should be investigated and in particular the continuous horizontal and vertical kiln type retorts.

3. A first order approximation of the cost of a continuous horizontal retort capable of handling 2.5 t/h of bagasse would be Rs9.2-10.2 M ($900 000-1 M) fob, whilst that of the vertical kiln type would be Rs8.2 M ($800 000) fob. In addition, there would be shipping, civils and local installation costs; the cost of a drier would be about Rs4.1 M ($400 000), and a disintegrator costing Rs1 M ($100 000) might also be required if a continuous horizontal retort were selected.

4. Carbonised bagasse would have to be briquetted and to be economically attractive a briquetting plant should have a throughput of at least 2 t/h. It would therefore be appropriate to have 3 or more carbonising plants, feeding a central briquetting unit. The cost of a complete briquetting plant would be of the order of Rs6.2 M ($600 000).

5. The existence of a domestic market for non-briquetted charcoal needs to be investigated. Any excess could be exported as briquettes to Western Europe and/or the Middle East; here the market investigation must also confirm that the physical properties of bagasse charcoal are suitable for use by those markets. TPI are carrying out a study of the world charcoal market in early 1982.

6. A feasibility study of charcoal production costing Rs384 000 ($37 500) is recommended. A pilot plant would cost Rs16.4 M ($1.6 M).

7. It is concluded that bagasse is not a suitable raw material for biogas production.

8. Producer gas is somewhat similar in composition to the pyrolysis gases produced in charcoal retorts and its production and utilisation will be studied by MSIRI.

1. CHARCOAL

Introduction

1.01 Laboratory tests have indicated that charcoal briquettes, a high grade solid fuel, can be produced from bagasse. The potential to transfer this technology to an industrial scale, together with its commercial feasibility, should be explored. If successful, it would increase the fuel value and make it cheaper to transport.

Technological considerations

1.02 Production of charcoal from bagasse involves two distinct processes:

a) carbonising the "green" feed material; and

b) briquetting or pelleting the finished product.

In addition it is necessary to pre-dry the bagasse to a suitable moisture level, burning flue gases and/or the pyrolysis gases generated by the carbonising stage.

1.03 Carbonising process There are various types of reactor which have been used for charcoal production. Two are suggested for further investigation with bagasse, although other types should not be ruled out at this stage.

1.04 Continuous horizontal retort Aldred Process Plant Limited, of Worksop, Notts, UK, produce a continuous carbonising unit typical of this type, consisting of a specially constructed, split-run, sealed kiln with a gas-tight surrounding jacket. The drive end of the unit is fixed and the kiln is suspended from roller units to allow for expansion and contraction.

Raw materials after drying and pulverising are hopper fed to the intake, and are passed mechanically through an externally heated zone. The carbonisation by-product gases are drawn from this area and are burned in a refractory-lined furnace at elevated temperature. Hot spent gases from this are adjusted and circulated through the kiln jacket to produce the required carbonising temperature.

The drive is supplied with a variable speed unit so that the moving bed speeds can be adjusted as required.

From the flow diagram (Figure 1) it can be seen that a drier can be employed, using the spent combustion gases from the furnace. The space requirement for a typical layout employing two parallel carbonising units with a common furnace is 20 m^2.

1.05 The first plant of this type is operating in Kenya, using coffee husks, while a second installation is nearing completion in Tanzania to utilise cashew wastes. There is no plant operating utilising bagasse at present, and a detailed study would have to precede any such installation.

1.06 Of particular concern is the moisture content of the bagasse fed to the kiln. The manufacturers have specified a level not exceeding 10% moisture, which would require a substantial drying plant. In addition, in order to increase the bulk density of the feed, it has been suggested that some additional disintegration, and maybe compression, of the bagasse would be necessary. Both these stages would add considerably to the plant costs.

1.07 The estimated cost of a plant capable of handling 2.5 t/h of bagasse DM is in the region of $900 000-$1 M FOB (Rs9.2-10.2 M). All shipping costs, civils and local installation would be additional. The cost of a rotary drier using flue gases at 320°C would be of the order of $400 000 FOB (Rs4.1 M) while a disintegrator might cost up to $100 000 (Rs1 M).

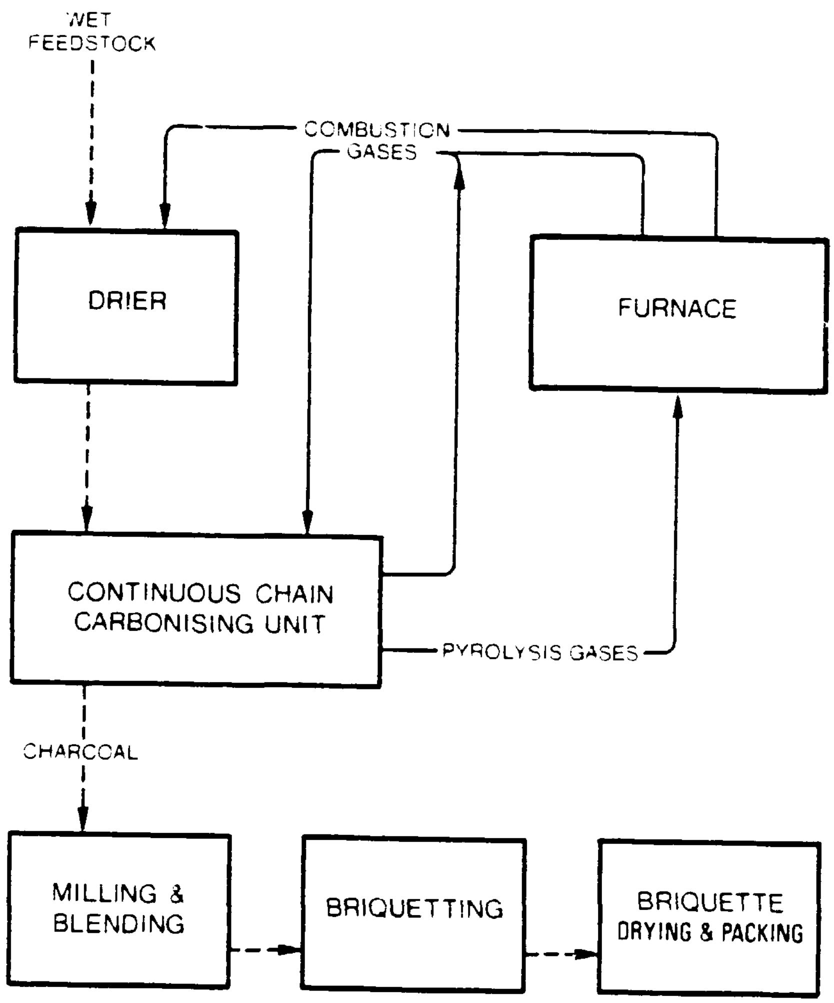
1.08 <u>Vertical kiln type</u> There are various types of vertical kiln reactor. One commercial enterprise in Mauritius is discussing the installation of a Georgia Tech type of kiln, and the following description applies to that system.

The bagasse is pre-dried on a pneumatic bed drier, and fed by auger into the top zone of a vertical kiln. Approximate dimensions of the kiln would be 10 m high by 1.5 m diameter. The upper cone, from where the pyrolysis gases are withdrawn, would be stainless steel, while the main body of the kiln would be of mild steel construction with refractory lining. A paddle type stirrer, driven by a geared motor continuously disturbs the bed of carbonising material.

Following ignition of the feed material, the rate of combustion and carbonisation is controlled by the supply of air, which is delivered through jets at the base of the kiln.

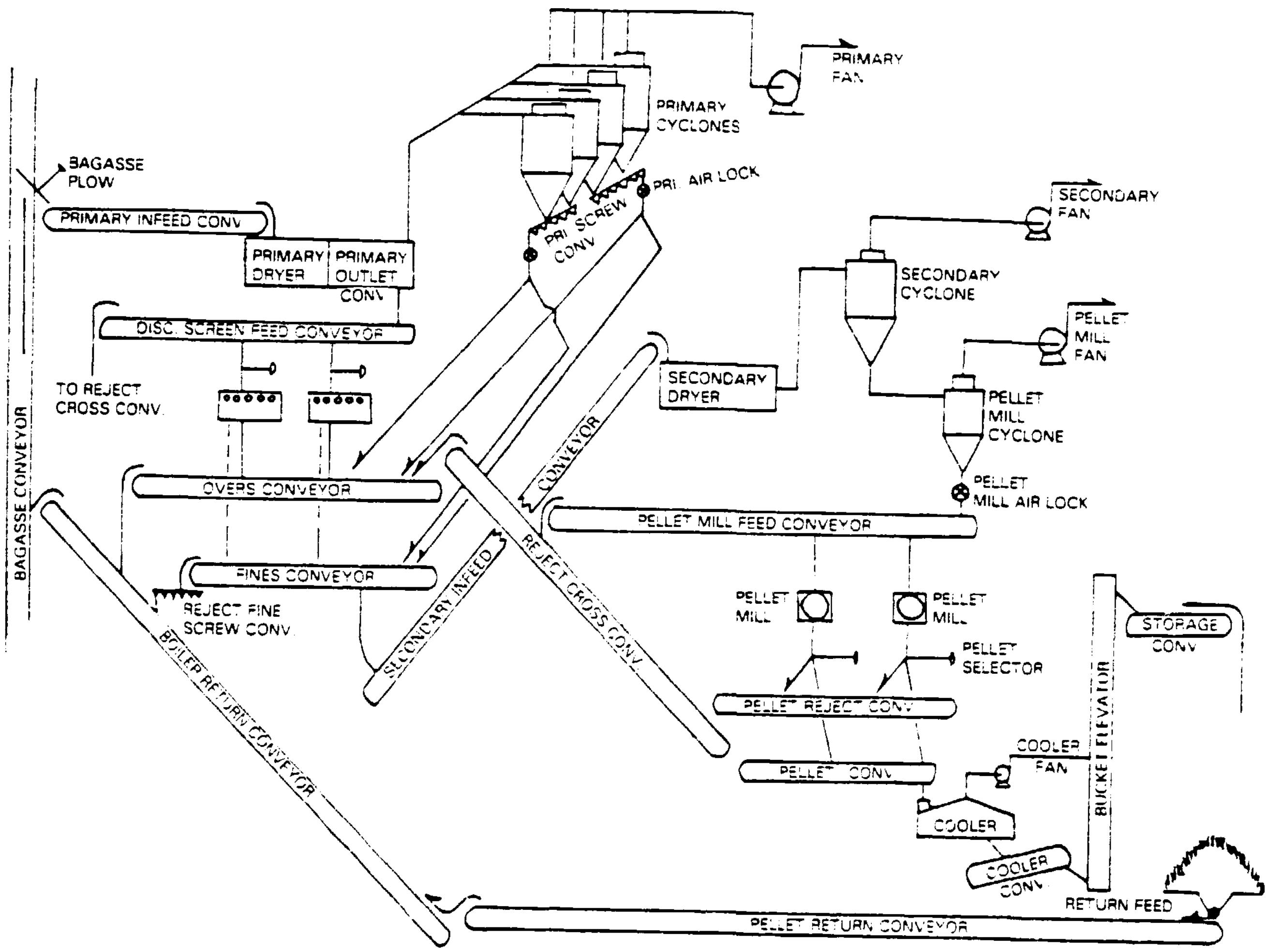
The process is continuous (Figure 2), with carbon being removed by auger from the base of the kiln, where it is quenched with water to prevent spontaneous ignition.

Layout of Horizontal Retort Carbonisation Plant Fig.1



Layout of Bagasse Pelleting Plant

Fig. 2



Source : SUGAR y AZUCAR, August 198?.

The pyrolysis gases can be fired in a special furnace but more probably would be burned in the factory boilers along with bagasse.

1.09 Although there are a number of these plants operating in the United States on wood wastes, no plant has been built to utilise bagasse. As with the horizontal kiln, questions such as the moisture content, particle size of feed, yield of carbon, and calorific content remain to be answered. One manufacturer with whom discussions were held stipulated 35% moisture with no additional disintegration of bagasse, but this would be subject to trials on a plant scale.

1.10 A typical installation would have a capacity of 2.5 t bagasse per hour (dry basis). The yield could be varied between 10 and 35% of char, depending on the air supplied. Thus an installation could be operated to produce a low charcoal yield and high gas yield and vice versa, depending on the bagasse supply and the overall factory heat balance.

A first order approximation of the cost of a plant of this capacity would be $800 000 FOB (Rs8.2 M) excluding shipping, civils and local installations costs. The cost of a pneumatic drier is estimated at $100 000 (Rs1 M).

1.11 Briquetting process The carbonised bagasse would normally be mixed with some form of inert extender to give a longer burning briquette. The choice of extender would depend on local materials available but in the Mauritian context it could be crushed oyster shells or some similar material. A binder is added to form the briquettes, and here molasses is the most likely material, although normally starch is used for this purpose. Figure 3 shows a typical layout of a briquetting plant. The carbonised bagasse, extender and binder are fed from hoppers to a mixer, and thence to the roller presses. The pressed briquettes are then fed to band driers where they are dried from about 10 to 4% moisture prior to packing.

1.12 To be economically attractive the plant should operate at at least 2 t/h. It would therefore be appropriate to have 3 or more carbonising plants feeding a central briquetting unit. The cost of a complete plant, including packing equipment, would be in the region of $600 000 (Rs6.2 M), although this might be reduced if a second hand briquetter was bought.

1.13 Operating costs As no plants operating on bagasse have yet been built, no costs are available. Costs given by one manufacturer for a typical wood waste plant were as follows:

	US$/t
Carbonisation process, including labour and maintenance	36
Extender	5
Other materials	4
Briquetting and packing	25
	70
	Rs 683

On a bagasse plant there would be additional drying costs, and possibly the cost of disintegrating the bagasse.

Market considerations

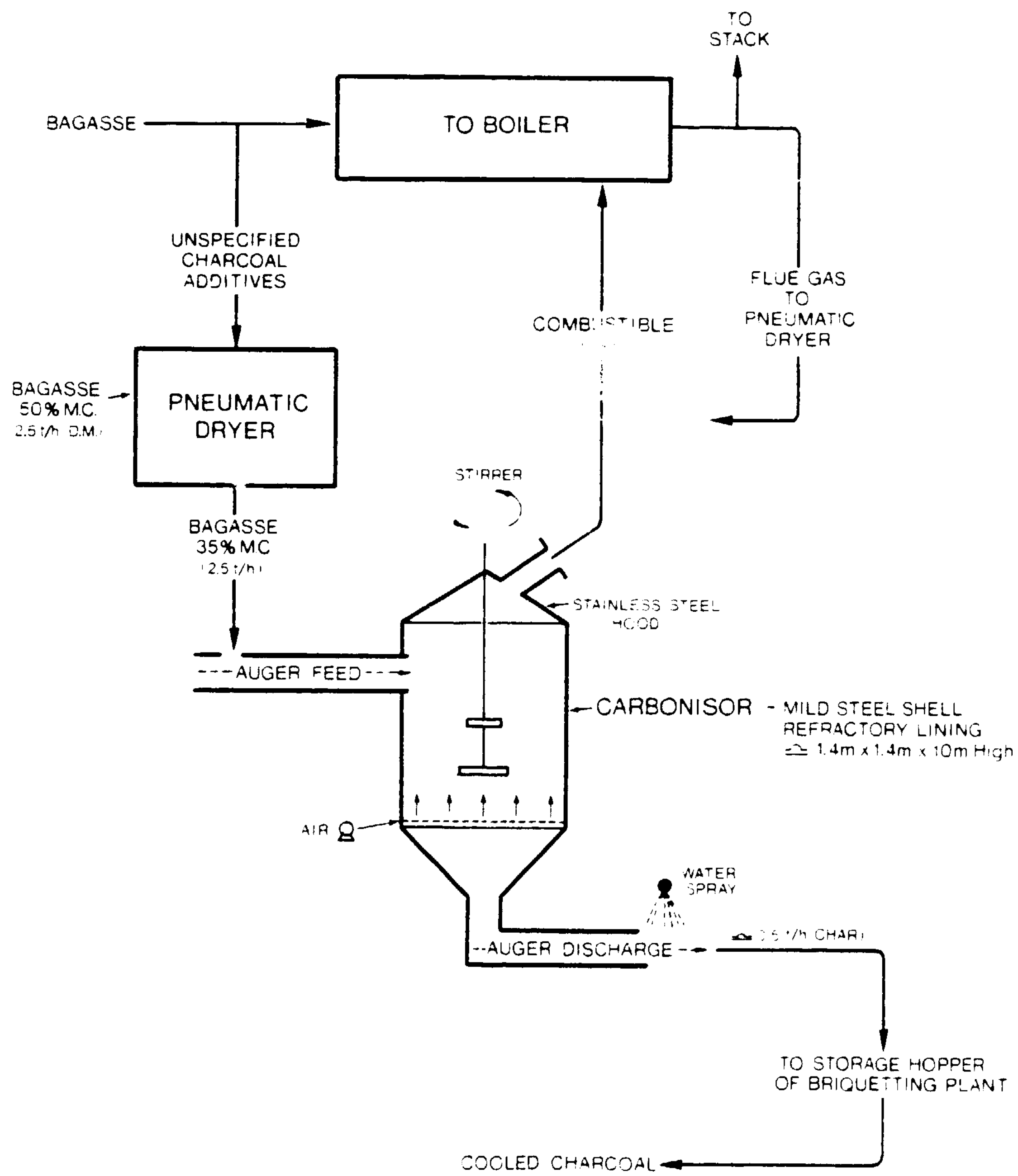
1.14 Production and trade According to FAO, world charcoal production amounted to nearly 16 M t in 1979. However, only about 2% entered international trade; production is predominantly for domestic use. The major exporters of charcoal are the USA, Indonesia, the Philippines, Thailand, Spain, Hungary and Yugoslavia.

1.15 The major importers of charcoal are the USA, Canada, Japan, Malaysia, France and West Germany. End Table 1 shows a steady increase in quantities traded. The statistics make no distinction between different types of charcoal and it is estimated that about 25% of these totals is accounted for by coconut shell charcoal. Trade tends to take place on a regional basis. Imports by Singapore and Hong Kong are often re-exported to other Far Eastern destinations. Spain and Eastern Europe are the predominant suppliers to the Western European markets, where West Germany and France are the major users. Import statistics for the Middle East are unreliable and the total of 20 000 t may be an underestimate of the quantities sent to these markets.

1.16 Uses Charcoal has both industrial and domestic uses. It may be used as an industrial fuel; metal smelting is its major application in Malaysia. Increasingly it is being used in the production of activated carbon, although primarily coconut shell charcoal supplies this market. Domestically it is consumed in many countries of the world as a cooking fuel. In West Germany and France, large quantities are sold for use in barbecues.

Layout of Vertical Kiln Carbonisation Plant

Fig.2



BAI MAU 2

1.17 Prospects for Mauritius Demand for charcoal in Mauritius is low. Normally a charcoal production industry is based on a domestic market; charcoal is a bulky, low value commodity and packing and freight charges are a large part of the price of traded charcoal. This also encourages trade on a regional basis.

1.18 The stated intention in Mauritius is to agglomerate the charcoal into sticks for sale in the domestic market, entailing a change in cooking fuels. Further production would be of briquettes. This is an expensive process which would require sales to the more high value barbecue markets, of which West Germany and France probably offer the best prospects. In the Middle Eastern markets the primary use is also for cooking; in view of the proximity of these markets to Mauritius, they merit detailed investigation.

1.19 Markets undoubtedly exist for charcoal. However, it is important that any technical investigations undertaken on the production of bagasse charcoal are done in conjunction with further market studies. Two questions are of particular importance. The first is whether bagasse charcoal has the necessary physical properties to compete in these markets; the second is whether it can be produced and marketed at a competitive price given the packing and freight costs.

1.20 The Tropical Products Institute (TPI) will shortly be undertaking a survey of world charcoal markets, and will be in a position to give more detailed information on them when the study is complete.

Recommendations

1.21 It is recommended that a feasibility study for a pilot plant is carried out. This would take 6 man-months and cost Rs384 000 ($37 500). If the feasibility study is in favour of a pilot plant, this should be installed at an estimated maximum cost of Rs16.4 M ($1.6 M).

2. BIOGAS

2.01 The production of fuel-biogas from organic waste products is a routine operation in many sewerage treatment plants, and agricultural waste products are used in countries such as China and India; in addition, the treatment of manures from intensive livestock projects is now becoming important, partly to prevent pollution but also to produce energy in the form of biogas.

2.02 All feedstocks for biogas projects have one thing in common: they are readily biodegradable by metnogenic bacteria. They contain high proportions of cellulose and/or simple polysaccharides, plus suitable sources of other nutrients such as nitrogen and phosphorus. Lignins and hemicelluloses are resistant to biodegradation, and a given weight of lignin protects an approximately equal weight of cellulose from biodegradation 1/.

2.03 Pre-treatment with strong alkalis does break down these resistant substances 2/ but such processes are unlikely to be justified in the production of biogas.

2.04 The range of chemical composition of bagasse 3/ on a DM basis is as follows:

Cellulose	26-43%
Hemicellulose	17-23%
Pentosan	20-32%
Lignin	13-22%

Typically, something in excess of 50% of the raw bagasse would not be biodegradable by methogenic bacteria (without expensive pre-treatment). It must be concluded, therefore, that bagasse is not a suitable raw material for biogas production, except in so far as small proportions (especially of the finer material) could be included with animal manures or similar materials where these are the main inputs.

3. PRODUCER GAS

3.01 Bagasse is a suitable raw material from which producer gas may be made. The pyrolysis gases produced from charcoal plants are more or less similar in composition to producer gas. MSIRI intend to investigate the production of producer gas from bagasse.

1/ Pijkens, B A (1981). Symposium papers, Energy from Biomas and Wastes, V, pp 463-475. Inst. Gas. Technol.: Chicago.

2/ Wang, L H, Kuo, Y C and Chang, C Y (1980). Proc. XVII Cong. ISSCT, pp 2533-2543.

3/ Lacey, J (1980). Proc. XVII Cong ISSCT, pp 2442-2461.

END TABLES

Imports of charcoal a/ (t'000)

End Table 1

	1977	1978	1979	1980
America	51	59	61	NA
of which				
Canada	36	23	26	8
USA	14	36	34	37
Asia	143	135	158	NA
of which				
Hong Kong	19	19	21	34
Japan	44	42	56	66
Malaysia	42	44	44	NA
Singapore	19	10	16	22
Middle East b/	18	19	20	NA
Other	2	2	2	NA
Europe	117	118	141	NA
of which				
Belgium/Luxemburg	6	5	6	7
France	21	19	32	36
German Fed Rep	27	31	26	49
Italy	6	6	9	13
Netherlands	9	7	8	11
Norway	5	5	8	15
Sweden	7	6	14	NA
Switzerland	8	5	8	7
UK	12	13	14	16
Yugoslavia	5	11	4	NA
Other	12	11	11	NA
Total	312	312	360	-

a/ Includes coconut shell charcoal.
b/ Includes Bahrain, Iran, Iraq, Kuwait, Qatar and Saudi Arabia.
Source: FAO Yearbook of Forest Products.
Country Trade Statistics.

APPENDIX 8

BY-PRODUCTS: FIBRE PRODUCTS

CONTENTS

SUMMARY

1. Paper produced worldwide from bagasse pulp mixed with wood pulp is currently 2 M t/y, using 1.2 M t bagasse pulp; this represents 15% of the pulp made from non-wood fibres. Newsprint production from bagasse has been tried in Louisana, USA and in Cuba, but with no commercial success. Two mills using the Simon Cusi process have opened in the last three years in Peru and Mexico, of 110 000 and 100 000 t/y capacities respectively. Neither is yet operating at full capacity, and it is not possible to say if they will succeed commercially. When the mills are in full production Peru would be self sufficient in paper and Mexico would still be a net importer.

2. A 125 000 t/y mill has been proposed for Mauritius. The technical aspects are discussed. It is recommended that the plant is not built for a variety of reasons, of which the most important are that all the bagasse used would need to be replaced by fuel oil as a source of energy in the sugar factories, and that the required export market for the paper is uncertain. Nor is a small scale paper mill recommended, since it would produce a relatively high cost product which would also need to be exported.

3. Particle board was manufactured at St Antoine from 1971 to 1979. The company is now in voluntary liquidation. The reasons for its unprofitability are partly technical and partly market ones. The result was that the company was unable to operate at anything like full capacity, nor to generate sufficient revenue to meet its costs. Efforts are currently being made to reopen the mill to produce particle board largely for an export contract. The plant appears to be in good condition. Existing investors would probably need to provide funds for two new pieces of equipment. If the mill reopens, it is recommended that management seek technical advice on board production and use; the cost is estimated at Rs384 000 ($37 500).

4. Fibre board, medium density fibre board and cement bonded particle board are not recommended since they would make products in the same markets as the existing particle board mill. In addition cement and sugar are notably antipathetic.

1. INTRODUCTION

1.01 This Appendix deals with fibre products which may be made from bagasse. The first group is pulp and paper. Feasibility studies have been made for a paper mill in Mauritius, but no decision has been reached to build one. Accordingly the subject is dealt with in somewhat general terms.

1.02 The second group is particle boards. By way of contrast to pulp and paper, a manufacturing unit operated in Mauritius from 1971 to 1978. This is examined in some detail, and conclusions are drawn and recommendations made.

1.03 The third group comprises other miscellaneous fibre products.

2. PULP AND PAPER

Present position with regard to the use of bagasse

2.01 Bagasse was first examined as a potential fibrous material for pulp and paper manufacture more than one hundred years ago, and the first successful commercial production (in Peru and Taiwan) occurred more than forty years ago. Currently 1.2 M t of pulp are produced from bagasse each year; this is usually mixed with wood pulp, and is used in the production of 2 M t of paper. This quantity of pulp is about 0.9% of the total quantity produced for papermaking, but 15% of the pulp made from non-wood fibres.

2.02 Bagasse pulp is used as a major component (sometimes the only fibrous component) of a wide range of papers including writing and printing grades, corrugating medium tissues and boards and as a minor component in wrapping and sack papers. The techniques for pulp and papermaking are well-established.

2.03 Interest in the use of bagasse as a raw material for newsprint goes back to the 1950s and two mills were built, one in Cuba and one in Louisiana, USA. Both mills used a process involving prehydrolysis of partially depithed bagasse, followed by alkali digestion and bleaching. Neither mill was a commercial success. However, experiments to develop a suitable pulping process have continued and there are a number of proposals for mills. The two most advanced are the Induperu mill at Trupal, Peru and Mexicana de Papel Periodico, at Tres Valles, Mexico.

2.04 Newsprint grades of pulp have been produced from bagasse by a number of different processes; both mills mentioned in the previous paragraph are using the Simon Cusi process. In this process the depithed bagasse is given a mild chemical digestion which is sufficient to digest fibres from the core of the cane but leave those in the rind almost intact. The two parts are separated by a screening process, the pulping of the resistant part completed by mechanical means and the two grades of pulp recombined for bleaching. Newsprint is made using 75-80% bagasse pulp, 5-10% semi-bleached softwood kraft pulp, 10-15% groundwood pulp and 5-7% filler clay: the last two components are to improve capacity and ink absorbency of the paper. The Peru mill has a rated capacity of 110 000 t/y of paper, the Mexican mill 100 000 t/y; each mill is reported to have cost $120 M (Rs1 230 M).

2.05 The Peru mill started production late in 1978 and the Mexican one in mid-1979. It is too early to say whether these mills are commercially successful. In its first full year the Peru mill had problems with the supply of electric power, water and bagasse which prevented continuous operation, but the company reports that "further improved quality will be achieved as the operating staff and quality control personnel gain more experience with this kind of facility". Published statistics show that the production of newsprint in Peru was over 50 000 t higher in 1980 than in 1978 and during the same period Mexican production increased over 20 000 t. This indicates that both mills appear to be contributing to newsprint production but at well below their rated capacities.

The proposal for a paper mill in Mauritius

2.06 The proposal for Mauritius is a mill with a rated capacity of 125 000 t/y. This proposal has been the subject of several feasibility studies. As far back as 1969, Sandwell and Company Limited, in a report for the United Nations 1/, proposed a 33 000 t pulp mill, but concluded that the return was inadequate.

Technical considerations

2.07 Quantity of bagasse required The amount of bagasse needed to produce 1 t of pulp would depend on the efficiency of depithing and the severity of the digestion. If the bagasse was dry and fully depithed it would be expected to yield 40-45% of dry fully digested chemical pulp or 55-60% of dry pulp suitable for

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1/ Sandwell and Company Limited (1969) Utilisation of bagasse in Mauritius. P 2368/2: United Nations, New York.

newsprint. The 1976 Sybetra study 1/ allows a yield of 25% pulp using 50% dry bagasse. In doing so they appear to have allowed for some further loss of pith at the pulp mill.

2.08 Supply of bagasse Sugarcane production in Mauritius is such that there is an ample supply of bagasse (average 1972-79 excluding cyclone years 1.727 M t) potentially available for a 125 000 t/y pulp and paper mill. However, bagasse is used as fuel in sugar mills and has other uses. In present circumstances there would be insufficient bagasse, surplus to factory requirements for fuel, for the pulp and paper mill; so that some method of replacing bagasse at present used as a fuel would be necessary if were to be available for pulp production. The method proposed in the 1976 Sybetra study was to select a small number of sugar factories and to supply them with new oil fired boilers. The sugar factories would be given their total oil requirement and all of their bagasse would then be purchased by the pulp mill. The cost of these boilers must be included in the investment cost of the pulp and paper mill, thus increasing the total investment; at the present price of oil, the cost of bagasse to the pulp mill would be higher than the cost of wood to many pulp mills outside Mauritius. Alternative methods of releasing more fibre may have been studied and discarded. One suggestion, for detailed study if it is decided to proceed with the proposal, is to supply a larger number of sugar factories with depithing equipment, depith all of the bagasse and use the resulting pith with the minimum amount of fibre as fuel. This might release enough fibre and would have the advantage that all the material transported to the pulp mill is useful fibre. It has the disadvantage that, since most of the sugar factories are small, none of the depithing machines would be used to their full capacity. However, it might reduce the cost of high grade fibre to the pulp mill.

2.09 Cost of bagasse A major component in the cost of bagasse is its value as a fuel. Opportunity costs calculated in paragraph 7.10, Appendix 7A are in the range Rs212-281/t ($20.68-27.39) based on a fuel oil equivalent, and (paragraph 7.11, Appendix 7A) Rs126/t ($12.31) based on coal at a central coal fired power station. Other components entering the cost of bagasse delivered to a pulp mill are the baling cost at the sugar factories and the transport costs. It is estimated that the average cost of bagasse (coal basis) delivered to the pulp mill would be Rs220/t ($21.46), depending on transport distances. Using this price for bagasse it is estimated that the fibre

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1/ One of several feasibility studies.

required for pulp would cost Rs871/t pulp ($85); the cost of wood for 1 t of groundwood pulp could vary from around $25 (Rs256) in Chile, $45 (Rs461) in Southern USA, $63 (Rs646) in Canada and $80 (Rs820) in Scandinavia.

2.10 Processing method The proposal is for a mill using the Simon Cusi process. Although this process has been chosen for the mills built in Mexico and Peru, a technical report prepared for UNIDO points out that it is in two stages and produces only a small proportion of bagasse pulp. It is suggested that serious consideration should be given to the more common single stage processes, although the fact that no newsprint mill exists using a single stage process makes it difficult to draw conclusions.

2.11 Water The technical report prepared for UNIDO points out that, while it is proposed that the the paper mill use water from the Ferney power station as process water, there is insufficient water to keep the power station in continuous operation in the dry season. As it is not possible to run a large paper mill on an intermittent basis, the supply of water needs more study.

2.12 Supply of long fibre pulp It will be necessary to include a proportion of long fibre pulp in the newsprint in order to give it adequate strength. Aloe, (Furcraea giganta also known as Mauritius hemp), is proposed. There is no literature on the use of this species for pulp and papermaking, but the information available indicates that it is similar to sisal. It is doubtful if this fibre could be pulped in the same equipment as bagasse. Tests would be required to determine the pulping conditions to be used, and whether the result could be used as a replacement for softwood kraft pulp in newsprint. In any case it is an undesirable technical complication which would be best avoided. Semi-bleached softwood kraft pulp should be imported.

2.13 Chemical recovery The importance of chemical recovery as a way of reducing both chemical consumption and pollution cannot be over-emphasised. When bagasse is used it is not possible to have a completely closed system because of the build up of impurities, especially silica, in the system. The Sybetra proposals include chemical recovery plant and the disposal of sludge at sea.

2.14 Effluent treatment Most of the process water will reappear as effluent. The Sybetra proposals include a treatment plant to produce clear water with a BOD reduced to an acceptable level for discharge into the river, which in turn flows into the tidal lagoon system. However, a

BOD level that is acceptable for discharge into the river at maximum flow may well be too high at minimum flow rates. There will be also some solid sludge to be dumped at sea. Care is required in selecting dumping areas so that tidal currents do not bring contaminated material back to the shore.

Market considerations

2.15 The most important overall consideration is the availability of a market. Every country that is a major producer of paper using bagasse pulp is an importer of paper. There is no evidence of any substantial import/export trade of any grade of paper containing bagasse or bagasse pulp. When their new newsprint mills are in full production Peru will be self-sufficient and Mexico will continue to be an importer of paper.

2.16 In Mauritius the position is different; in 1979 (the peak year) only 3 500 t of newsprint and paper were imported (End Table 1). Virtually all the paper produced will need to be exported. To achieve this there must be potential markets in which the product must compete in quality and price.

2.17 It is difficult to ascertain where the markets will be. On a world-wide basis the 1980 production of newsprint of 25.7 M t was about 93% of installed capacity. There is reserve capacity of about 1.9 M t. Expansions of 5.3 M t have been announced and are expected to be available during 1981-82: much of this new capacity being in North America. It appears that there will be either very large quantities of wood based newsprint seeking markets or large unused capacity available in the mid-1980s.

2.18 Newsprint produced in Mauritius has been suggested for markets in East Africa and India. Export possibilities in the African market are very doubtful; in 1979 the whole continent (excluding South Africa) imported 91 000 t. There are reports of mills being built in Nigeria, Tanzania and Kenya and either the Nigerian or the Tanzanian mill by itself would turn Africa into a net exporter.

2.19 India is a more difficult market to assess. In 1980 production capacity was 55 000 t and production 48 000 t; thus there is thus some spare capacity. Imports were 312 000 t. This certainly indicates there there is a market that could absorb the Mauritius production. However Indian imports are volatile, as shown during the period 1970-79:

1970	1971	1972	1975	1977	1979
t	t	t	t	t	t
144 000	207 000	154 000	101 000	168 000	232 000

Throughout this period the only Indian newsprint mill produced 40-50 000 t/y. Consumption is subject to wide swings. The prospects for imports are affected by a second newsprint mill of 75 000 t/y due to have opened in 1981. Consequently India is a possible market, but probably not a reliable one. The Indian sugar industry is almost ten times as large as that of Mauritius; thus if bagasse were a viable material for newsprint, the processing could equally well take place in India. Assuming that Indian consumption steadies at around its 1980 level of 360 000 t/y (since this was a 25% increase on the previous year it seems reasonable to assume a plateau for a few years) and that the Indian mills produce at 90% of capacity, Mauritius would need to capture one third to one half of the total Indian imports of approximately 240 000 t/y in 1982: at present India imports from six countries, suggesting that in general the trade prefers not to rely on a single supplier.

2.20 Since the preceding paragraph was written, IBRD have announced a $100 M (Rs1 025 M) loan for a pulp and paper mill in Tamil Nadu State. It would produce 100 000 t newsprint or 80 000 t quality paper (or a mixture), using bagasse and eucalyptus fibre. The estimated completion date is 1985.

2.21 On quality the bagasse based newsprint should have adequate strength, although it is likely that it would have a substance 1/ of 52 g/m^2 against 48 g/m^2 for most wood based newsprint. This would mean that the price that could be expected for bagasse newsprint would be lower than for wood-based. The bagasse newsprint would usually have poor opacity and ink absorbency: in Peru and Mexico it has been necessary to include groundwood to overcome these difficulties. The import of groundwood pulp could cause additional technical problems and further increase production costs.

<u>Assessment of the proposed mill</u>

2.22 It is not considered advisable for Mauritius to proceed with the establishment of a large scale bagasse based pulp and paper industry, principally for the production of newsprint because:

a) the viability of the technology is as yet unproven on an industrial scale;

b) the capital and operating costs of replacing bagasse at present used as fuel in sugar factories, by imported fuel oil or coal will be high;

1/ 'Substance' is defined as the weight per unit area in g/m^2; it is also known as 'grammage'.

c) there will be major problems in the supply of one essential raw material - water;

d) disposal of effluent has yet to be satisfactorily provided;

e) export markets for the paper that could be produced may be difficult to find and are at best uncertain; and

f) the bagasse would not be available to make steam and electricity, and energy would be a net input rather than an output (compare the production of ethanol or electricity).

Assessment of the possibility of establishing a small scale plant

2.23 Technical considerations The manufacture of pulp and paper on a small scale presents different problems from those encountered in large scale plants. The availability of bagasse and water are probably not constraints although there may be doubt about water supply in the dry season.

2.24 The first problem is to decide what is the smallest possible size. The minimum size of an efficient chemical recovery plant is a very important factor. It is usually considered that recovery plants must be large; around 50 000 t/y minimum for wood based kraft mills, but for pulping agricultural residues using a caustic soda process they could be smaller.

2.25 A recovery plant is necessary; otherwise 1 - 1.5 t of organic material for each tonne of pulp produced, together with all the chemicals used, will go to the river or sea. A small recovery unit suitable for a mill producing 40 t/d of pulp (13 000 t/y) has been developed for caustic soda cooking of agricultural residues. Such a plant would have an efficiency of 75% in terms of chemical recovery and would reduce the organic matter discharge to 0.25 - 0.4 t/t of pulp. The cost of such a plant would be $5.6-$6.4 M cif (Rs57.4-65.6 M).

2.26 The capacity of the paper mill would be larger. Most grades of paper containing bagasse need a proportion of wood pulp which would need to be imported. On average 1.2 t of bagasse pulp will yield 2 t of paper. Therefore, unless the paper mill is restricted to those grades that contain a very high proportion of bagasse pulp, the paper mill would have a maximum output of no more than 22 000 t/y. Such a mill would need an investment of approximately $56 M cif (Rs574 M).

2.27 The establishment of a mill of 25 000 t/y capacity would mean that production would be well above consumption in Mauritius (6 000 t in 1980). Therefore, the successful operation of even a small mill will depend on export markets. Unfortunately the product of small mills tends to be more expensive than that of large mills, and small mills usually prosper only where there is a sufficient local protected market.

2.28 As will be seen from the data provided below the investment per tonne of pulp and paper capacity is much larger for small than it is for large mills. This information is provided in two parts because mills with a capacity below 30 000 t/y do not usually include a recovery plant.

Annual capacity (t)	Relative investment (per t of capacity)
a) Mills above 30 000 t/y	
35 000	2
65 000	1.5
100 000	1.2
130 000	1.1
165 000	1
b) Mills below 30 000 t/y	
6 500	2
13 000	1.3
25 000	1

2.29 Production costs of large mills are also lower and the effect of economies of scale on production costs is much greater if recovery plant is not included in the small mill. Consequently, the selling price of paper made in small mills must be relatively high.

2.30 Although small mills are technically possible the trend is for bagasse based pulp and proper mills to have a minimum capacity of 50 000 t/y. Even in Mexico, where bagasse pulping is so successful that they produce more than 20% of the world's bagasse pulp, no mill producing less than 15 000 t/y has remained in production more than five years

2.31 Assessment of a small scale plant A small pulp and paper mill based on the use of bagasse is not recommended for Mauritius for the following reasons:

a) even the smallest mill would produce much more paper than the local market can absorb; and

b) the relatively high cost of paper produced in small mills make it very unlikely that export markets could be found.

3. PARTICLE BOARD

Present position

3.01 Particle board is a sheet material made from reconstituted wood chips or fibres from agricultural and forestry residues. The ones most commonly used in industry are planer shavings, first timber thinnings, flax shives and bagasse. It is manufactured worldwide with a total production of approximately 38 M m^3 (1978) which has a regional distribution of 95% developed world markets (North America 19%, Western Europe 49%) and 5% developing world markets.

3.02 The general manufacturing process principle of platen pressing of particle board is common to all types of raw material. Particles of known size distribution are produced by means of chipping and flaking machines and hammer mills. After screening for dust and other foreign matter the particles are dried to a moisture content of 3-5% prior to mixing with 8-10% of a synthetic glue such as urea formaldehyde resin. At this stage compounds such as insecticides, fungicides and waxes (to increase moisture resistance) can be added. The sprayed particles are felted into a mat and then inserted into a heated platen press where they are consolidated under pressure and temperature into rigid boards. Following pressing, the boards are trimmed to standard size and sanded to provide a smooth surface and consistent thickness ready for sale and further finishing.

3.03 Particle board is normally made in sheets of 2.4 x 1.2 m or larger, with a density range of 600 to 750 kg/m^3 at thicknesses between 3 and 40 mm. It has good strength characteristics (typically 180 kg/cm^2 and 3.5 kg/cm^2 respectively at a thickness of 19 mm for bending and tensile strength perpendicular to the plane). The material can be nailed, screwed, sawn and used in a similar fashion to wood, although it causes a high rate of wear for normal tools. It has many applications in furniture, flooring, partitions, shelving and, with a suitable waterproof protection, externally as roof decking and cladding.

3.04 In 1969 Sandwell 1/ proposed an 11 200 t particle board mill for Mauritius at a total cost of $13.9 M. Half the output was to be exported to East Africa. They concluded that the return was not sufficiently attractive.

3.05 A particle board factory was established by the Universal Board Company Limited (UB) in 1971. The company, which was granted a Development Certificate, built the factory next to the St Antoine sugar factory at a total cost of Rs5.13 M. Capital was provided from four main sources:

a) Shareholders including Harel Mallac, St Antoine Sugar Estate and the major wood importers/wholesalers. The Development Bank of Mauritius (DBM) was the largest, investing Rs250 000 in preference 'A' shares. In addition there were over 200 small holders of ordinary shares. The total share capital amounted to Rs2.02 M.

b) DBM provided long-term secured loans of Rs1.64 M.

c) The Mauritius Commercial Bank had granted overdraft facilities amounting to Rs1.45 M at 31 May 1979, secured on a floating charge.

The German machinery suppliers, Siempelkamp, provided credit for half the cost of plant and machinery. This loan was in Deutsche marks over five years at the bank rate of interest (8-10%). It was repaid out of special loans from institutional shareholders amounting to Rs1.57 M.

3.06 The capacity of the factory was 3 750 t/y of particle board (15 t/22 hr day for 250 working days), this being the smallest production unit commercially available. It was operated under a management contract with the St Antoine factory. Annual average production amounted to around 750 t of boards in thicknesses varying from 4 mm to 30 mm. A special order for 49 mm boards was also made. The production was sold entirely on the local market where it was in competition with imported plywood. The main use was in office partitioning and furniture. Due to high freight costs the boards were not competitive in export markets.

1/ Sandwell and Company Limited, Op cit.

3.07 From the start UB faced problems, and it accumulated losses until the company when into voluntary liquidation in 1979. The plant, which is still in good condition and in working order, could be made operational quickly. Should the factory be reopened, the only additions which might be needed would be a second sanding machine and a glueing machine, together costing Rs0.6 M ($58 000). The present sanding machine has inadequate capacity.

3.08 There were many reasons for the lack of success of UB 1/. These are divided here into technical, market, and financial; however, as most technical considerations had market effects - and so on - allocation to the three headings is necessarily somewhat arbitrary.

Technical considerations

3.09 There is no apparent reason to expect technical problems to arise from the processing of bagasse into particle board at the plant installed by UB. The manufacturing techniques, process problems and the properties of particle boards produced using varying raw material inputs (bagasse, resin, hardener, wax and other additives) are well known and plants have been established in several sugar growing areas. This plant was designed, installed and commissioned by a company with a great deal of experience in the utilisation of agricultural residues for particle board manufacture, and the machinery and equipment were fabricated by leading companies in the field.

3.10 Technical problems arose however. An early one was that the humid climate of Mauritius is conducive to growth of fungus on particle board. This was cured by adding a fungicide to the glue, but it gave the product a bad image.

3.11 A more serious problem has been the variable quality of the products. It had a very wide tolerance on thickness causing problems in secondary manufacturing industries; users complained that it was difficult to nail or screw without splitting; board sizing and machining were difficult because of the very high cutter wear; and it was rough and required a lot of finishing and painting. No veneered board was made after the first year. The users' reactions, together with inferences of a gradual reduction of board standard (variable density, and low bending and tensile strength) strongly indicate a lack of quality control in the manufacturing process and of managerial effort to ensure that the customer fully understood how to use the board.

1/ Raffray, J M (1980) L'usine de panneaux a particules - post mortem. PROSI Bulletin Mensuel No 137, PROSI: Port Louis, Mauritius.

Market considerations

3.12 Clearly as already mentioned, the technical problems had adverse market effects. Many of the marketing difficulties also, had technical origins.

3.13 A market study undertaken by UB before the factory was established suggested that in 1970 there was a total market for 1 200 t/y of boards. By 1979 this market was estimated to rise to 3 500 t/y.

3.14 Particle board competes on the local market with plywood. Imports have risen from 437 000 m^2 in 1970 to 1.32 M m^2 in 1978 (End Table 2). They appear to have fallen since 1978; however, due to a re-classification of the trade statistics this figure may not be directly comparable with the earlier ones. Due to the recession and cut-backs in construction it is likely that imports have fallen since 1978, but not to the extent suggested by the statistics.

3.15 Particle board of 4 mm thickness has a density of 700 kg/m^3; therefore 1 t of board is equal to approximately 360 m^2. This would suggest, based on import figures, a market size for particle board and plywood together of 1 200 t in 1970 and 3 700 t in 1978, agreeing with the market research figures. However plywood is imported in a range of thicknesses mainly varying between 3 mm and 18 mm. By taking the 4 mm thickness, therefore, these must be regarded as conservative estimates of the market size. Even so, they illustrate the fact that in order to operate at anywhere near full capacity, the factory would need to supply a high proportion of the current plywood market.

3.16 From an alternative viewpoint, it has been estimated that on average 1 t of board produced by the factory was equivalent to 160 m^2. The average annual sales level of 750 t is equivalent to 120 000 m^2 - less than 10% of total imports in 1978. Care must be taken in using this figure since particle board could have taken quite a high percentage share of the market for thicker boards. Nevertheless it illustrates the low penetration particle board achieved in the domestic market.

3.17 The boards were 10 x 4 ft (3 x 1.2 m) whilst imported boards were 8 x 4 ft (2.4 x 1.2 m) or 6 x 4 ft (1.8 x 1.2 m) and thus more convenient for users to handle. It would have been possible to reduce the length of board produced, but at the expense of an equivalent fall in production. alternatively boards could have been sawn.

3.18 When UB started manufacturing, the importers of plywood cut their prices to meet the competition from the factory. Even so, the particle boards were sold at lower prices than plywood.

3.19 The standard thickness of particle boards is 19 mm. Production of thinner boards is more expensive, mainly due to the proportionally higher wastage in sanding and to the lower productivity. When producing 4 mm boards the capacity of the factory was reduced to around 10-12 t/day.

3.20 Despite repeated requests to the Government, no protection was granted against imports in the form of higher import duties on competing products or by giving UB a quota on the local market. After the factory was liquidated import duties on plywood and similar products were raised. Currently there is a fiscal duty of 30% and a general customs duty of 20%. However, since most imports come from the Far East these are granted a preferential customs duty of zero. Most plywood imports thus enter at a duty of 30%, since raised by budget surcharges to 36.3%.

Financial considerations

3.21 Costs were higher than anticipated, especially for electricity, fuel oil and labour. The cost of insurance increased due to the quantity of unsold product in the factory. At the same time, however, the price of imported plywood also increased.

3.22 At full capacity the factory needs 10-12 000 t of bagasse annually and it was assumed that this could be obtained entirely from St Antoine. This proved not to be case even at low production and bagasse had to be brought in from neighbouring factories. The cost of baling and transporting this bagasse was about Rs100/t.

3.23 The devaluation of the Mauritian rupee against the Deutsche mark entailed much higher than expected repayments on the suppliers credit.

Assessment

3.24 Future prospects It will be difficult to re-open the factory to supply the total local market profitably. UB estimate that an annual production of 1 500 t of board will now be required to break even. On their estimates this is about 50% of the total market. Even if the market size has been slightly underestimated, particle board will need to take a large proportion of the plywood market before the factory breaks even. The product itself might also be improved by veneering or painting, although this has cost implications which will adversely affect its price competitiveness against plywood.

3.25 The most satisfactory way to re-open the factory would be on the basis of a long term market contract to at least ensure that a break-even point could be reached. At the time of the team's visit to Mauritius the possibility of a contract for 3 000 t/y with a South African company was being investigated. If this is successfully negotiated, full capacity would be reached with less reliance on the domestic market. A new Development Certificate should be obtained, giving certain tax advantages.

3.26 Technical recommendations It is essential that the specifications and quality levels are constantly maintained. Large and/or frequent variations from these will inevitably lead to adverse consumer reaction. Consistent quality can only be assured by close attention to detail in the critical processes and by undertaking standard quality control procedures.

3.27 It is also essential that the customer fully understands the fabrication techniques to use in the construction and furniture industries. Advertising matter should be produced indicating areas of utilisation and standard practices, and advice should be available when required. Facilities should be provided for the training of craftsmen in all aspects of using particle board and also of supervisors from local industries. Many fixtures and fittings are available for use with particle board; UB management should be fully conversant with these and should provide them where necessary.

3.28 The wear rates on tools may be reduced by using carbide-tipped saws and cutters. However these are expensive, and they need special grinding equipment to maintain sharp cutting edges. UB might therefore help all types of end users (and promote board utilisation for the plant) not only by cutting boards to size as demanded by the customer but also by offering a tool sharpening and repair service.

3.29 Management should seek technical advice from an organisation with experience in particle board production, with particular emphasis on quality control and end use.

The following programme is suggested:

1st year	One month before and two months after recommissioning of the plant, and one month later in the year.
2nd and 3rd years	One month per year.

The total input is 6 man-months. The cost is estimated at Rs384 000 ($37 500); this assumes that accommodation and transport would be made available at St Antoine.

3.30 Revenues and production costs Management of UB informed the team that the contract with the South African purchaser was priced at Rs2 700 fob Port Louis ($427), to give a profit of 10-15% on manufacturing costs. The profit (at 15%) on 3 000 t/y would be Rs1.67 M/y ($193 000) before interest.

3.31 Detailed costs since supplied by the liquidators, also for 3 000 t, show a selling price of Rs3 786/t ($436) and a manufacturing cost of Rs3 428 ($395) before interest. This is a margin of 9.5%. The break-even point is Rs2 474/t (Rs1 383/t before interest). If the price of the board is increased to Rs4 000/t, the margin becomes 14.3%, and the break-even point is Rs1 871/t (Rs1 046/t before interest). The import cost of the equivalent plywood would be Rs5 462/t ($630) or Rs7 430/t ($857) including duty. The costs in paras 3.30 and 3.31 are before the recent devaluation of the Mauritian rupee, and the costs of imported plywood will since have increased materially.

3.32 A comparison of these costs with those for 1977/78, as shown in UB's annual accounts (see End Table 3), reveal increased variable costs, much as expected. The cost of bagasse at Rs100/t ($9.76) is about 80% of the opportunity cost of Rs128 ($12.31) ex-factory, and makes no allowance for baling and transport. This is based on a coal fired central power station; the opportunity cost by reference to fuel oil is in the range Rs212-281/t ($20.68-28.31, para 7.11, Appendix 7A). Costs in this paragraph are post-1981 devaluation; the pre-devaluation opportunity cost of bagasse was Rs104/t (Annex to Appendix 11).

3.33 Four points of interest arise elsewhere:

a) The fee chargeable by St Antoine has risen from Rs321 000 ($37 000) in 1977/78 to Rs1 222 000 ($141 000). The fee covers the cost of all inputs by St Antoine, including insurance and carriage to Port Louis and is predominantly viable with production (rising from Rs385/t ($44) to Rs637/t ($73)); it has been treated as a variable cost in the previous discussion of break-even points.

b) Depreciation is charged on historical (principally 1971) costs.

c) Interest charged has risen from Rs424 000 ($49 000) in 1977/78 to Rs725 000 ($83 600) in 1981/82. About Rs65 000 ($7 500) would be interest on new equipment; the remaining Rs246 000 ($28 400) represents partly an increase in the bank overdraft rate, and partly interest on unpaid interest during the period since closure.

d) The most recent costs include a contingency of Rs896 000 (Rs299/t) ($103 300 and $34.50/t). This presumably includes cost increases due to inflation.

These, and indeed all aspects of the costs, would need to be checked by investors considering a financial reconstruction of UB. It is to be hoped that a selling price may be obtained which would generate a cash flow to repay all loans within a reasonable time, say 5-7 years. The total indebtedness at 31 May 1981 was as follows:

	Rs M
Long term loans	1.64
Special loan from shareholder	1.57
Bank overdraft	1.45
New machinery	0.50
Unpaid interest (say)	1.00
	6.16
	($757 000)

The cash flow at a selling price of Rs4 000/t, and at the costs supplied by the liquidator, would be:

	Rs M
Sales	12.00
Costs	11.00
Gross profit	1.00
Add depreciation	0.43
	1.43
	($165 000)

If attained, this cash flow would repay the indebtedness in under five years. Costs in this paragraph are based on pre-1981 devaluation figures and exchange rates.

4. OTHER FIBRE PRODUCTS

Fibreboard

4.01 Fibreboard is defined as a sheet material generally exceeding 1.5 mm in thickness manufactured from ligno-cellulosic fibres with the primary bond derived from the felting of the fibres and their inherent adhesive properties. Sometimes small quantities of bonding agents are used, and additives such as paraffin wax to decrease the amount of water absorbed by the bond are included. FAO statistics recognise two grades of fibreboard: compressed and non-compressed. In the UK (and many other English speaking countries) compressed fibreboard is called hardboard, and non-compressed insulating board.

4.02 Compressed fibreboard (hardboard) is usually 3-13 mm thick with a density of 900-1 200 kg/m^3. It has a wide range of non-structural uses including concrete form materials, ceiling boards, low cost roofing, underlay for roof tiling, internal wall linings, floor covering and built-in cabinets.

4.03 Non-compressed fibreboard (insulating board) is usually 12-25 mm thick with a density of 250-400 kg/m^3. Its main use is to provide sound and thermal insulation to ceilings and walls. The most common raw material is wood, but fibre residues such as bagasse and straw are also used.

4.04 The raw material is given a mild chemical cook using lime, caustic soda or neutral sodium sulphite (around 2 or 3% chemical on dry material) for 15 to 45 minutes at 170°C. The softened material is then reduced mechanically, often in a disc refiner, to a rather coarse pulp. In some cases the chemicals are omitted and the raw fibrous material is steamed before mechanical treatment.

4.05 The boards are formed by a wet-felting process in which the fibres suspended in a large volume of water are formed into a continuous wire mesh. Water drains through the mesh and then the mat of fibres is carried through a series of presses either on the mesh or on wool felts. When the mat emerges from the presses it contains about 30-40% solids. The mat is cut by a knife at right angles to the direction of travel into lengths, which are placed in a heated platen press where they are compressed and dried using pressures of up to 71.4 kg/cm^2 and temperatures between 175°C and 225°C. Non-compressed boards are dried by passing through a long (up to 300 m) steam heated drier.

4.06 A conventional plant of this type would produce 100-1 000 t/d of board (approximately 100-1 000 m^3 of compressed fibreboard or 300-3 000 m^3 of non-compressed). A 100 t/d plant would require an investment of around $25 M (Rs256.2 M).

4.07 Smaller plants, down to 20 t/d, using conventional processing have been reported but they are usually relatively more expensive to buy and operate. For example a 50 t/d plant would require an investment of $13 M (Rs133.25 M).

4.08 A number of very small (10 t/d) less mechanised plants have been built. They operate on the same principles of pulping, wet-forming and pressing but instead of forming the boards on a continuous wire mesh, they are made in forming boxes about 2.5 x 1.2 m. This appreciably reduces the cost of machinery and also makes it easier to operate the plant on an intermittent basis and thus match the mill's output with the local market.

4.09 In semi-dry formed fibreboard the fibres are obtained by conventional pulping processes and, having a moisture content of about 50%, are formed into a mat by air-layering. It is necessary to use a binding agent and the board is weaker and of less homogeneous formation then wet felted board.

4.10 The worldwide production of fibreboard in 1979 was 18 M m^3. The rate of growth over the last 10 years was 2.3%/y; the main reason for this low rate is competition from particle board production which has grown at a rate of 9.3% to reach 41 M m^3 in 1979. The main reasons for the success of particle board relative to fibreboard are:

a) particle board can be used for all of the purposes for which compressed fibreboard is used and is also used for some structural purposes; and

b) the investment cost of a particle board plant is about half that for a fibreboard plant of equivalent size.

4.11 <u>Assessment</u> It is inappropriate to consider the production of fibreboard from bagasse in Mauritius because:

a) investment would be high for a conventional fibreboard plant producing 100 t/d from wood, and probably higher if bagasse is used as the raw material; and

b) the market can be fully met by the present particle board mill.

Medium density fibreboard

4.12 Medium density fibreboard (MDF) is a relatively new panel product made using small particles, similar to those used for fibreboard, but forming the board by a dry process similar to particle board. The board has a density of around 700 kg/m^3. The fibres are obtained by steaming the raw material and then disintegrating it in a disc refiner. Resin and paraffin wax are added to prepared fibre which, after drying, is felted to form a fibre mat which is pressed under temperature and pressure. The panel product formed has a homogeneous structure with uniform texture and properties, and no identifiable grain can be seen on the face or edges. Smooth surfaces allow for all types of high quality finishing including painting, printing and veneering; edges can be profiled using normal machine tools for similar finishing, making MDF an ideal product for the high class panel furniture industry.

4.13 The technology involved is possibly more sophisticated than wet felting processes. Plants tend to be large, with production of about 150 t/d, but designs exist for smaller plants. A 50 t/d (70 m^3/d) plant would need an investment around $9 M (Rs92 M). This would indicate an investment cost between that for a particle board plant and a wet-formed fibreboard plant.

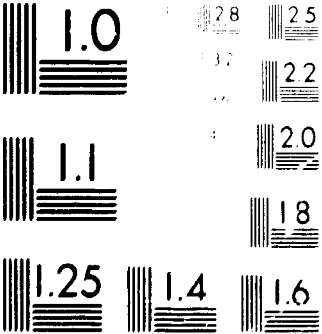
4.14 Since the market for panel products in Mauritius is insufficient to support the existing particle board plant, it is inappropriate to consider establishing an MDF plant.

Cement bonded particle board

4.15 Bagasse can be used as the basic raw material for a cement bonded particle board. The production process is comparable to that of the manufacture of resin bonded particle board; the end product is mainly intended for use in the construction industry. However, sugar and cement are not compatible, and in the event of production being undertaken the preparation stage of the raw material would have to be rigorously controlled. Prior to this stage, technical suitability should be proven by an in-depth laboratory trial, and economic and marketing feasibility established.

4.16 Recent (1980) estimates have shown that the total investment costs for a cement bonded particle board plant are about $10.5 M (Rs108 M). The plant would employ some 105 workers on a 3-shift system and have similar water and energy requirements as a resin bonded particle board plant. Cement would have to be imported at high cost and the product would in part be aiming at similar markets as particle board and plywood in the construction industry. It is unlikely with the limited market - and in the light of the problems of the particle board mill - that any new venture of this kind would be profitable.

END TABLES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2.0
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1.25
1.4
1.6

Mauritius: imports of newsprint and paper — End Table 1

	Newsprint		Printing and writing paper		Total	
	t	Value Rs'000	t	Value Rs'000	t	Value Rs'000
1976	816	2 608	1 304	7 892	2 120	10 500
1977	1 038	3 653	1 584	9 219	2 622	12 872
1978	1 370	4 359	1 603	7 165	2 973	11 524
1979	1 750	6 684	1 791	9 779	3 541	16 463
1980	1 392	7 525	1 811	14 366	3 203	21 891
Values in $'000						
1976		435		1 315		1 750
1977		609		1 537		2 146
1978		727		1 194		1 921
1979		911		1 333		2 244
1980		868		1 657		2 525

Source: Customs and Excise Department.

Mauritius: imports of plywood

End Table 2

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979 a/
Volume ('000 m^2)										
Total	437	458	608	649	805	869	1 024	1 178	1 322	740
Of which from:										
Singapore	203	209	285	336	388	497	479	587	741	583
Malaysia	73	111	130	88	27	38	119	205	122	51
Taiwan	86	93	163	120	306	211	264	229	195	6
Value (Rs'000)										
Total	1 652	1 694	2 452	3 917	6 083	5 792	10 103	11 014	12 233	14 481
Of which from:										
Singapore	614	612	945	1 948	2 493	2 838	4 094	4 901	7 197	10 885
Malaysia	220	360	420	370	306	340	1 257	1 879	1 307	1 164
Taiwan	453	461	814	779	1 993	1 547	2 242	2 207	1 946	226

Notes: a/ Covers items classified under SITC (Revised) 631.21, 1970-78 and BTN 44.15, 1980.
b/ 1980 statistics not available.

Source: Customs and Excise Department.

Universal Board Company Limited: manufacturing costs 1977/78 and 1981-82 (estimated) End Table 3

	1977/78 835 t		1981/82 1/ 3 000 t	
	Total Rs'000	Unit Rs/t	Total Rs'000	Unit Rs/t
Variable costs				
Bagasse)	1 031	1 234	900	300
Chemicals)			3 315	1 105
Electricity	288	344	1 160	387
Fuel oil	161	193	1 247	416
Insurance)			150	50
Carriage)	321	385	540	180
St Antoine fee)			1 222	407
Sub-total	1 801	2 156	8 534	2 845
Fixed costs				
Repairs and maintenance	91	109	210	70
Depreciation	389	466	430	143
Administration	133	159	100	33
Guarantee fee	-	-	113	38
Sub-total	613	734	853	284
Contingencies	-	-	896	299
Interest	424	508	725	242
	2 838	3 398	11 008	3 670

Sources: 1977/78 Annual accounts.
1981/82 The liquidators (de Chazal du Mee and Company).

1/ 1981/82 costs were prepared before the 1981 devaluation.

APPENDIX 8

APPENDIX 9

BY-PRODUCTS : OTHER

CONTENTS

SUMMARY

1. Furfural may be produced from bagasse but the minimum size for an economic plant is 6 000 t/y (requiring 65 000 t/y bagasse). In view of the fact that the local market for furfural in Mauritius is negligible and export prospects are not promising, it is not recommended that furfural production should be considered.

2. Large scale sugarcane wax production has not proved profitable outside Mauritius and the wax is now only traded on the world market in very small quantities. In these circumstances it is not proposed to consider sugarcane wax production.

1. FURFURAL

1.01 Furfural is primarily used as a feedstock for the production of furfuryl alcohol, an intermediate chemical in the manufacture of foundry resins. Furfural is also employed in the extraction of butadiene from refinery gases, and as a selective solvent in the refining of high quality lubricating oils.

1.02 Furfural is extracted from agro-industrial residues. Bagasse is one of these; it contains 8-10% furfural (DM basis) which may be recovered by hydrolysis of pentosans contained in cellulosic materials with steam at high pressure and temperature. A minimum pentosan content is 18%; bagasse has 20-32% (para 2.04, Appendix 7(B)). The resulting hydrolysate contains 57% furfural which is distilled using a series of distillation columns. The hydrolysis reaction is usually carried out in a number of batch reactors, but continuous reactors have also been developed. Between 16 and 20 t steam are required to recover one tonne furfural. Furfural production is not economic at below 6 000 t/y, and such a plant would require 65 000 t/y bagasse.

1.03 Total world production is over 200 000 t/y, the major producing countries being the USA and the Dominican Republic. Production in the latter country is based on bagasse. The major markets for furfural are in the USA, Western Europe and Japan and demand has been growing in recent years. However, the local market for furfural in Mauritius is negligible and prospects for exporting furfural are not promising. Over 90% of the world's supply is controlled by the Quaker Oats Company which is able to create unfavourable trading conditions for newcomers to the furfural market. The market in the neighbouring African continent is already supplied from plants in Kenya and South Africa. It is not recommended that furfural production be examined further in Mauritius.

2. SUGARCANE WAX

2.01 Sugarcane wax is a hard, brittle, dry wax, with similar characteristics to other hard natural vegetable waxes. The potential supply of this wax from the sugarcane crop far exceeds that of any other vegetable wax. However, production on a large scale has not proved profitable or worthwhile in view of the very limited market outlets.

2.02 The wax market may be divided into two major categories - natural and synthetic waxes. The former include animal, vegetable and mineral waxes. Trade estimates suggest that the total size of the animal and vegetable wax market is around 20 000 t/y with the USA, the EEC and Japan being the major consumers. One-third of this total is accounted for by the animal waxes, of which beeswax is the most important. The balance is supplied by the vegetable waxes. Carnauba wax, produced almost entirely in Brazil, and candelilla wax from Mexico, dominate this trade. Other vegetable waxes of less significance include esparto, Japan wax, ouricoury and sugarcane waxes. Total world trade in these minor vegetable waxes does not exceed 2-3 000 t/y, and sugarcane wax itself is only traded in very small quantities.

2.03 The long-term trend in the natural wax market has been one of decline in the face of increasing competition from the synthetics, although at present the market has probably stabilised. Synthetics have the major advantage that their specifications can be guaranteed and that supplies and prices fluctuate less, which makes them preferred by some end-users. For these reasons, the production of sugarcane wax is not considered.

APPENDIX 10 MARKET DATA

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CONTENTS (cont)

SUMMARY

This appendix contains market data which are not used in previous appendices for the assessment of the various by-products under discussion therein. It examines the economic background to local markets, ie economic growth and population forecasts. It then discusses the markets for three sugar industry products which have been shown to have opportunity costs (ie prices in alternative markets) in the by-products study. These are sugar itself, molasses and potable alcohol. Domestic and foreign markets for these are examined and their future development assessed.

1. INTRODUCTION

Economic growth

1.01 Following a period of relative stagnation in economic growth through the later 1960's, the Mauritian economy showed an impressive rate of growth in the early and mid-1970's. Between 1970 and 1978, for example, GNP grew at nearly 8% per annum in real terms. The sugar price boom of 1974 enabled particularly high rates of growth and investment to be achieved in the mid-1970's. In 1978 GNP was estimated at $830/head 1/.

1.02 Since 1977, however, the country has faced severe economic difficulties. The collapse of sugar prices in 1976 caused balances of payments to deteriorate whilst the overall economic situation was aggravated by continual rises in wages and costs and high rates of inflation. GNP, whose growth had slowed to 3%/y in real terms in 1978, was more or less static in 1979. By October 1979, the declining situation led to a devaluation of the rupee by 30%. Poor harvests, caused by cyclones and bad weather in 1980 and 1981, have further deepened the economic recession. GNP is estimated to have fallen by 5-8% in real terms in 1980 and is expected to fall again slightly in 1981. The rupee was devalued a further 20% in early October 1981.

1.03 Future economic growth will, as always, depend primarily on the size of the sugar harvest and world sugar prices. Even if these are maintained at around average levels, only a slow recovery from the recession is anticipated. Data supplied by the Ministry of Economic Planning and Development suggest that GNP in real terms will grow at a average rate of only 1.5%/y between 1981 and 1985, thereafter increasing gradually to 2%/y by 1990.

Population

1.04 The last census carried out in Mauritius in 1972 enumerated the population at 826 000. Since the previous census in 1962, the average rate of population growth had been 1.9%/y. Figures for estimated population since 1972 are given below. These show that by 1980 the population had grown to 927 000 at an annual average rate of 1.5% since 1972. When analysed on an annual basis it can be seen that since the last census there has been a steady increase in the rate of population growth. This has been due to the relatively larger numbers of women entering reproductive age.

1/ World Bank Atlas (1980)

Population of Mauritius

	Total ('000 mid-year)	Annual growth rate (%)
Actual		
1972	826	-
1973	835	1.1
1974	846	1.3
1975	857	1.3
1976	868	1.3
1977	882	1.6
1978	896	1.6
1979	911	1.7
1980	927	1.8
Forecast		
1985	1 009	1.7
1990	1 097	1.7

Sources: Central Statistical Office.
UNIDO Team estimates.

1.05 In future, the population is expected to continue to grow at the comparatively higher rates experienced in recent years. The Two-year Plan 1/ forecast an annual growth rate of 1.8% over the period 1977-82. The actual increase has been slightly lower than this, averaging 1.7% between 1977 and 1980. Following discussions with the Ministry of Economic Planning and Development it was agreed that this average rate of 1.7% should be used for the population forecasts in this report. Thus, as shown above the population is expected to have reached 1 009 000 by 1985 and 1 097 000 by 1990.

2. SUGAR

Sales in Mauritius

2.01 All sales of sugar in Mauritius are undertaken by The Mauritius Sugar Syndicate, figures for both local sales and exports being given in End Table 1. The size of the local market is about 40 000 t for both direct and industrial

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1/ Ministry of Economic Planning and Development (1980) Two-year plan for economic and social development 1980-82.

consumption, the majority comprising white sugar. Wholesale and retail prices for white sugar on the local market are fixed by Government and are currently Rs2.31 ($0.23) and Rs2.50/kg ($0.24) respectively. Prices for raw sugar are Rs1.71 ($0.17) and Rs1.90/kg ($0.19) respectively. Although these prices have been increased considerably over the past two years, they are still below the cost of production of sugar and sales are being subsidised by the industry.

2.02 Exports reached a record level of 686 000 t in 1973/74 (End Table 1), but have otherwise fluctuated between 620 000 t and 660 000 t over the past decade. Exceptions have been in the drought year (1971-72 - 590 000 t) and in years when cyclones have damaged the crops (1975/76 and 1980/81 - about 440 000 t each). The majority of exports are in the form of raw sugar, although small quantities of white and demerara sugar are sold to the EEC.Sugar exports by destination are recorded in End Table 2.

2.03 The EEC is the major market, the bulk of trade going to the UK. Mauritius has a quota in the EEC market under the ACP Protocol on sugar annexed to the Lomé Convention for 487 000 t of white sugar, equivalent to about 507 000 t tel quel (shipped weight). The price of raw sugar delivered under this quota is fixed annually by negotiations between the ACP countries and the EEC. In 1980/81 it was ECU 35.89/100 kg, basis 96° polarisation cif European port. For sales to the UK, this price was equivalent to £222.04/t ($431.50) - the ECU conversion rate to the 'green' pound was £1=ECU 1.61641.

2.04 At the time of the team's visit to Mauritius the negotiations for the 1981/82 price had not concluded, but it is expected that the price will rise by 7.5%-8.5%. In addition any Monetary Compensatory Amount (MCA) prevailing at the time of entry of a vessel to a community port is for the account of the ACP exporter. This may be positive or negative, depending on the relative strength of the commercial pound against other EEC currencies. Thus, in converting the ACP-EEC guaranteed price, the actual price received by Mauritius depends on the strength of both the 'green' pound and the commercial pound. This, and other less important factors, meant that the average cif price obtained for the 1980 quota sales to the EEC was £199/t 96° polarisation.

2.05 The balance of exports after the EEC quota has been met are sold on the world market. This market is managed under the International Sugar Agreement (ISA) to which Mauritius is a signatory. Under the Agreement Mauritius was allocated a basic export tonnage of 175 000 t raw value. In fact, due to poor crops, exports have been well below this level and in 1980/81 no sales at all were made to the world market.

2.06 When exports are made on the world market the most important destination is the United States. Mauritius sugar benefits from duty-free access to this market under the US Generalised System of Preferences (GSP). Small quantities of sugar are also normally sold to Canada, where again preferential treatment is granted. Prices on these markets are based on world prices.

2.07 For the year 1981/82 the sugar crop is estimated at 600 000 t. Besides the 507 000 t quota, Mauritius will also be shipping a further 47 000 t to the EEC under the "force majeure" provisions of the sugar Protocol to make up for the shortfall in deliveries in 1980/81. With local consumption approaching 40 000 t and a likely stock-holdings obligation of 10 000 t under the provisions of the ISA, the 1981/82 crop is already accounted for. Thus, for the second year running Mauritius is unlikely to export sugar on the free world market.

<u>The world sugar situation and outlook</u>

2.08 Average world sugar production, consumption, export and money prices for 1973-80 were as follows:

Production	83.5 M t
Consumption	81.7 M t
Exports	17.2 M t
Prices	US¢ 13.15/lb
	US¢ 34.56/kg

Details are shown in End Table 3. Cane sugar, largely produced in developing countries accounts for over 60% of total production. Beet sugar, mainly produced in developed countries accounts for the remainder.

2.09 The balance of production and consumption has been characterised by relatively long periods of large surpluses, followed by shorter periods of small deficits. The majority of sugar is consumed in the country of origin, with some 20-25% of production being exported on the free world market. In addition, approximately 5 M t are exported under special agreements.

2.10 As a result of the relatively small proportion of world production being sold on the free world market, the size of surpluses or deficits is magnified causing prices to fluctuate widely. This is illustrated in End Table 3 which shows high price levels in 1974 and 1975 following the production deficits in 1973 and 1974. A similar situation arose in 1980. Production invariably expands strongly following periods of high prices. Since production is relatively inflexible downwards and consumption relatively unresponsive to price changes, this leads to periods of low prices whilst consumption catches up again.

2.11 In 1981, after two deficit years, production has once more expanded and current expectations are for a surplus of around 2 M t at the end of the year. An expected record EEC crop is one of the main reasons for this. In response prices have fallen from a high of 41¢/lb (90¢/kg) in October 1980 to 16¢/lb (35¢/kg) in July 1981 (see End Table 4), and have subsequently fallen to even lower levels.

2.12 In view of the nature of the sugar market, future prices can be expected to continue to fluctuate substantially. Projections must therefore be made for long-term trend values. In general, future demand for sugar is likely to continue to grow steadily. One may therefore assume that the long-run average price will approximate the cost of production from efficient newly established sugar projects necessary to meet this rise in world demand. The price level implied by this approach has been estimated at approximately 13¢/lb (29¢/kg) at 1977 prices, equivalent to 21¢/lb (46¢/kg) in constant 1981 terms.

2.13 This figure is below the actual average (unweighted) price during 1971-80 of 22¢/lb (49¢/kg) in constant 1981 terms. At the same time the ISA is aiming to maintain prices within a range of 13-23¢/lb (29-51¢/kg). Taking account of these various figures, a round estimate of 20¢/lb (44¢/kg) has been used in this report for future sugar prices. This is well above present prices and towards the top of the ISA price range. At the same time it is slightly below estimated production costs and below the average price over the last decade.

Future prices in Mauritius

2.14 As discussed above in 1980/81 no sales of sugar were made by Mauritius on the world market, and in 1981/82 a similar situation is expected. The reason for this has been the very low crop in 1980, followed by a poor 1981 crop. In a normal year Mauritius could expect to sell about 550 000 t to the EEC and on the local market, the remainder of the crop being sold on the world market. In an economic analysis the price used would be that obtained at the margin for sugar sales. Thus, for Mauritius, the marginal price would normally be the free market price.

2.15 In the section above a future world market price of 20¢/lb 44¢/kg was forecast. This is based on the ISA daily price, fob and stowed Caribbean port for raw sugar. Differences between freight rates from the Caribbean and from Port Louis to Northern Hemisphere destinations are so small in relation to the values of the cargoes that this price may, for the purposes of this report, be taken as equivalent to the fob Port Louis price.

3. MOLASSES

Background

3.01 The marketing of molasses in Mauritius is carried out by two companies - Mauritius Molasses Company Limited (MM) and Alcohol and Molasses Company Limited (A&M). The former buys molasses from 13 mills and all the planters. Of the planters share, 50% is then resold to A&M primarily to facilitate storage. This latter company also buys molasses from the other millers. On average MM is responsible for about 55% of total sales.

3.02 The two companies supply 50% each of the local distilleries' requirements, which currently average about 15 000 t/y. Production of alcohol in 1979 was 3.2 M ℓ 100°GL (End Table 9). In addition, on the domestic market, A&M sell molasses to certain estates for animal feeding and to the feed factories. Total use for animal feed is currently estimated at 6 000 t/y.

3.03 After supplying the domestic market the balance is exported principally to the UK. Amounts shipped to the USA show a steady decline. Total quantities of molasses exported by destination are given in End Table 5.

3.04 MM sell under a long-term contract with United Molasses Company Limited, a subsidiary of Tate and Lyle. The price under this contract is based on a formula applied to selling prices in UK, USA and continental Europe. Allowances are made for costs, eg freight, insurance, commissions, etc, to arrive at an fob price. The final price paid to the millers and planters is arrived at by deducting export duty and costs from this fob price. Both fob and ex-factory prices over recent years are listed in End Table 6.

3.05 In contrast A&M sell only two cargoes under long-term contracts, the remainder being sold on tender. The price they receive is therefore different to that received by MM but, taking one season with another, prices average out at much the same level.

Characteristics of the world market

3.06 The world market for molasses has fluctuated between 5 and 6 M t over recent years and represents about one quarter of total world production. This trade is almost entirely cane blackstrap molasses since most beet molasses is consumed within the country of origin. Although a by-product, the status of molasses has risen in recent years as markets have developed. Only a few years ago it used to present a disposal problem in some places.

3.07 The major markets for molasses are threefold - USA, the EEC and Japan. Imports by the USA, the largest market, halved between 1970 and 1980. Over this same period, however, the European market has more than doubled. In both these markets the major use of molasses is in animal feeds. The increased demand in Europe is a reflection of the rapid development of the compound feed industry over the decade, associated with the fact that EEC policies have kept cereal prices high, thus encouraging the use of other ingredients such as molasses in feeds. In the USA, on the other hand, the feed industry was already well developed in 1970 and thus had less potential for growth, whilst lower grain prices made molasses less competitive, especially in the late 1970s when molasses prices rose steeply. End Table 7 shows import statistics.

3.08 The market in the Far East has remained relatively static over the decade. Here the main demand is for industrial distillation and fermentation. The market in this region has remained more or less self-sufficient in terms of supplies.

3.09 Molasses prices have always been subject to wide variations; from 1977 they increased sharply until mid-1981. For example, ex-tank New Orleans prices rose from a low of around $40/t (Rs240) in 1977 to pass $120/t (Rs1 040) in the last quarter of 1980 and peak at around $130/t (Rs1 127) during the first half of 1981. Prices, however, have fallen rapidly recently as demand has declined and in the third quarter of 1981 were down to around $85/t (Rs737 pre-devaluation - Rs871 post devaluation).

Future prospects

3.10 In such a volatile market future prospects are hard to predict. Demand will depend primarily on the EEC animal feed market, where growth in compound feed production is unlikely to be as fast as through the 1970s. Prices will play an important part in this market since above certain levels other products may begin to replace molasses. New markets for molasses may also effect demand, especially so if any of the gasohol projects at present being proposed in various countries are implemented. As far as fob prices are concerned ocean freight rates are also likely to play a large part.

3.11 Discussions with a number of traders on likely future price levels for molasses gave a consensus of opinion that they could fluctuate over a wide range. It appears unlikely that the high prices of early 1981 can be sustained, whilst demand has increased sufficiently to ensure prices should remain above the low levels of the early 1970s. Within this range, therefore, an fob price of $75/t (Rs769) has been used for future sales of molasses from Mauritius. In view of the uncertainty about this figure it is proposed to carry out sensitivity analyses using a low forecast of $65/t (Rs666) and a high forecast of $85/t (Rs871).

Future internal prices

3.12 For the financial analyses in this report it is necessary to derive internal prices for molasses from the above fob prices. To obtain ex-factory prices, deductions must be made for export duty and for the costs of exporting. The former currently stands at 12.1% (10% plus two surcharge of 10% each). The costs of exporting include transport to the harbour, handling and loading, as well as charges for administration, depreciation and interest. Besides these deductions, adjustments also have to be made:

a) to allow for sales made on the local market (and, in particular, quantities sold at Rs50/t for the manufacture of methylated spirits); and

b) for the conversion from tel quel to 86° brix.

In the table in para 3.14, allowances for both these adjustments have been included under the heading of costs.

3.13 For 1980/81 costs (including adjustments but excluding export duty) for exporting molasses were Rs109/t ($10.63) this figure being used for the calculation of future ex-factory prices.

3.14 In order to obtain future delivered factory prices in Mauritius for molasses, transport costs must be added back to the ex-factory price. This cost will obviously vary with distance; current transport costs from the mills to Port Louis vary between Rs20-45/t ($1.95-4.39); an average of Rs33/t ($3.22) is used.

Price forecasts for molasses

		Base	Low	High
			$/t *tel quel*	
Fob Port Louis		75	65	85
			Rs/t *tel quel*	
		769	666	871
Deductions				
Export duty (12.1%)		93	81	105
Costs		109	109	109
Ex-factory price (86° Brix)		567	476	657
Transport		33	33	33
Delivered factory price (86° Brix)		600	509	690
	$	58.54	49.66	67.32

Source: UNIDO team estimates.

4. LIVESTOCK FEEDS

See Appendix 5

5. ETHANOL

Motor fuel (see Appendix 6)

Potable alcohol

5.01 The major use of ethanol in Mauritius is for the production of alcoholic drinks, this market accounting for some 80% of total utilisation. Supplies to the market are shared equally between the three distilleries, the ex-distillery prices of ethanol being fixed by Government, depending on the price of molasses, and currently standing at Rs7.50/ℓ at 100°GL.

5.02 Three companies supply the potable alcohol market in Mauritius - New Goodwill Limited (NG), Mauritius OK Distillery Limited (OK) and Gilbeys (Mauritius) Limited (Gilbeys) - bottling data for which are given in End Table 8. OK is a subsidiary of Harel Freres, which owns Beau Plan. NG and OK dilute and bottle the alcohol, while Gilbeys redistil the alcohol and produce a range of cane spirits and liquors. Only NG are allowed, thanks to a Government concession, to market their product as "rum".

5.03 Both the statistical evidence and discussions with distillers and bottlers confirm that the use of ethanol for alcoholic drinks has remained relatively stable over recent years. If anything consumption increased slightly until 1980, since when it appears to have decreased primarily due to the economic recession. The data in End Table 8 show the potable alcohol market to be 6.1 M ℓ at 40° GL in 1979 ie 6.7 ℓ/head. This is a high level of consumption and, in view of the current economic difficulties, the potential for growth in the market is limited and at best only likely to follow population growth at 1.7%. Considerable excess capacity exists at both the distilleries and the bottling plants, and capacity is not a constraint to growth.

5.04 The above discussion has only considered the domestic market for potable alcohol. In addition, Gilbeys have attempted to find export markets for their more up-market cane spirits with the brand name Green Island. So far, however, only very small quantities have been involved, destinations including the Far East, Malta and the UK.

Other uses

5.05 Besides the potable alcohol market, ethanol has a number of other uses in Mauritius (End Table 9). Primarily it is denatured for heating and lighting purposes (methylated spirits) and to produce denatured spirits. Molasses to produce methylated spirits is sold to the distilleries at a fixed price of only Rs50/t ($4.88), the ex-distillery price of ethanol for methylated spirits being fixed in turn at Rs1.40/ℓ ($0.14).

5.06 Small quantities of ethanol are used in the manufacture of a range of products including perfumes and cosmetics, medicines and drugs, and vinegar. Production of these items is geared to meet local demand and fluctuates around relatively low levels.

5.07 Exports of ethanol (rectified spirits) have been on an irregular basis, only involving small quantities. This is to be expected since it is not a widely traded commodity. The technology to produce ethanol is well known and any country with a sugar or starch feedstock can manufacture its own supplies. Thus even if markets are found they cannot be regarded as reliable in the long term. Furthermore, investment would be required in containers for internal transport and in harbour facilities, both of which could only be justified if large and regular markets were to be established.

Conclusions - local markets

5.08 Production of ethanol in Mauritius is presently undertaken with a view to satisfying local demand. The major use is in alcoholic drinks and, in both this market and in the other more minor markets, demand is currently relatively static. At best, the domestic market for ethanol will grow in line with population at around 1.7% per annum.

5.09 The only prospects, therefore, for increasing ethanol production are through finding export markets or developing new uses. Amongst the products currently produced from ethanol the only one to have any possibility of entering export markets on a regular basis is rum and this is considered in more detail below. The new use of ethanol as a partial substitute for gasoline is analysed in Appendix 6A.

Export markets for rum

5.10 Gilbeys are engaged in promoting export markets for their white "rum", brand named Green Island, but with no great expectation of success. They also sell locally a dark rum under the Green Island label.

5.11 Two distinct markets have developed for rum - the traditional market for "dark" rum and the recently developed market for "white" rum.

5.12 EEC The major importers of rum in the EEC are the UK, West Germany and France as is shown in End Table 10. Under the terms of the Lomé Convention quotas are fixed annually for the EEC member states' imports of rum to be allowed into the Community free of customs duty. As an ACP country Mauritius is entitled to benefit under these arrangements.

5.13 In France the ACP quota is small in terms of total imports, and has been allocated entirely to rum from Madagascar. The majority of supplies to the French market comes from the overseas departments of Martinique and Guadeloupe, and this market is effectively closed to new suppliers.

5.14 In the UK, rum consumption has increased steadily over the last decade and it will probably continue to grow slowly. This has been largely due to the development of the white rum market, led by Bacardi which has a near monopoly of this sector. White rum now accounts for 40-50% of all sales. The dark rum market is more competitive with a larger number of brands; however, these are well established and backed by large marketing organisations. Nine-tenths of dark rum consumption is accounted for by 12 brands. In such a highly developed market as this, it would be very expensive to introduce a new brand. Estimates suggest that to launch a new brand would require an initial promotional investment of about £1 M (Rs10 M), with follow-up annual expenditure at around half this level. The prospect of obtaining a market share sufficient to justify this level of investment is remote.

5.15 An alternative to selling bottled rum would be to supply rum in bulk to the importers for blending. However there is already surplus capacity in the Caribbean; rum importers are not looking for new sources. The strong traditional ties between producers and importers make it extremely difficult to break into this market.

5.16 The West German rum market is highly developed, with the competition long established. Consumer preference is for a small number of well recognised brands. The German market is shared by the pure rums and the rum verschnits. The latter are mixtures of rum and other alcohols of agricultural origin which provide a range of flavours. This is a highly specialised market, supplied by Jamaican rum, and effectively closed to new entrants. Within the pure rums, those originating in the EEC OCTs (overseas countries and territories) are favoured, making the remainder of the market highly competitive. As in the UK, the promotional expenditure required is not likely to yield worthwhile results.

5.17 USA The USA is the world's largest market for rum. Supplies from Puerto Rico and the US Virgin Islands, that are imported under preferential arrangements, dominate the market. Mauritius faces a tariff barrier and therefore is at a competitive disadvantage. It is not realistic to compete in the white rum market, dominated as it is by Bacardi. There is a reported resurgence of interest in dark rums in the USA and, despite the tariff barrier, a sales compaign on a regional basis is this sector might prove worthwhile.

5.18 Australia Is a rum producing country, importing only a small percentage of requirements. There is strong competition in the market and progressive excise increases in recent years have restricted its growth. Prospects for entering this market are therefore limited.

5.19 New Zealand Imports all its rum supplies. Consumption is mainly of dark rum, brands being well established. As with other markets, strong promotion would be necessary to break into the market, but prospects are probably better for a dark rum than in most other markets. However, a new distillery is reported to be opening in Fiji and this may limit the opportunities in this market.

5.20 Japan Imports rum mainly for use as a flavour in confectionery. This is a specialised market in which highly flavoured dark rums are required. For such a rum this market might be worth investigating.

5.21 In conclusion the prospects of Mauritius selling rum in quantity in the major world markets appear to be very limited. The white rum market, being dominated by Bacardi, needs very high promotional budgets to launch new brands. In the dark rum market the best prospects would appear to be the USA, New Zealand and Japan, but these markets are extremely competitive and therefore difficult to break into.

6. ENERGY FROM BAGASSE

Electricity (see Appendix 7A)

Other (see Appendix 7B)

7. FIBRE PRODUCTS FROM BAGASSE

(See Appendix 8)

8. OTHER SUGARCANE BY-PRODUCTS

(See Appendix 9)

END TABLES

Mauritius: sugar sales (t'000 *tel quel*)

End Table 1

Crop year (July-June)	Exports			Local sales			
	Raw	White	Total	Raw	White	Total	Total
1971/72	579	10	590	8	23	31	621
1972/73	625	28	652	7	27	35	687
1973/74	656	29	686	7	27	33	719
1974/75	644	13	657	5	35	40	697
1975/76	437	-	437	7	25	32	469
1976/77	637	15	653	-	37	37	690
1977/78	616	10	626	3	38	41	667
1978/79	614	4	618	3	37	40	658
1979/80	645	5	651	4	36	40	691
1980/81	440	3	443	3	28	32	475

Sources: Chamber of Agriculture and The Mauritius Sugar Syndicate.

APPENDIX 10

Mauritius: sugar exports by destination (t'000 tel quel) End Table 2

	1978/79	1979/80	1980/81
EEC	507	523	443
Canada	14	14	-
USA	95	114	-
Other	1	-	-
Total	618	651	443

Source: The Mauritius Sugar Syndicate.

World sugar statistics
(M t raw value)

End Table 3

	Production	Consumption	(Deficit)/ surplus	Net exports to free market	Price a/ US ¢/lb	Price a/ US¢/kg
1973	75.8	76.3	(0.5)	16.5	9.45	20.83
1974	76.4	77.3	(0.9)	16.2	29.66	65.83
1975	78.9	74.5	4.4	13.4	20.37	44.95
1976	82.5	79.3	3.2	15.6	11.51	25.37
1977	90.4	82.5	7.9	20.7	8.10	17.86
1978	90.7	86.2	4.5	17.4	7.81	17.22
1979	89.2	89.9	(0.7)	18.3	9.65	21.27
1980	84.4	87.5	(3.1)	19.5	28.65	63.16
Average	83.5	81.7	1.8	17.2	13.15 b/	34.52 b/

a/ ISA Daily price, fob and stowed Caribbean Port in bulk.
b/ Unweighted averages.
Source: International Sugar Organisation.

World market: monthly sugar prices a/ End Table 4

US¢/lb	1976	1977	1978	1979	1980	1981
January	14.02	8.34	8.77	7.57	17.16	27.78
February	13.50	8.59	8.48	8.23	22.75	24.09
March	14.79	8.98	7.74	8.46	19.64	21.81
April	14.05	10.04	7.59	7.82	21.25	17.83
May	14.54	8.95	7.33	7.85	30.94	15.06
June	12.99	7.87	7.23	8.14	30.80	16.38
July	13.21	7.39	6.43	8.52	27.70	16.34
August	10.02	7.61	7.08	8.85	31.77	-
September	8.13	7.31	8.17	9.90	34.74	-
October	8.03	7.09	8.96	11.94	40.55	-
November	7.88	7.07	8.01	13.68	37.81	-
December	7.55	8.09	8.00	14.93	28.79	-

US¢/kg	1976	1977	1978	1979	1980	1981
January	30.19	18.39	19.33	16.69	37.83	61.24
February	29.76	18.94	18.69	18.14	50.15	53.11
March	32.61	19.80	17.06	18.65	43.30	48.08
April	30.97	22.13	16.73	17.24	46.85	39.31
May	32.05	19.73	16.16	17.31	68.21	33.20
June	28.64	17.35	15.94	17.95	67.90	36.11
July	29.12	16.29	14.18	18.73	61.07	36.02
August	22.09	16.78	15.61	19.51	70.04	-
September	17.92	16.12	18.01	21.83	76.59	-
October	17.70	15.63	19.75	26.32	89.40	-
November	17.37	15.59	17.66	30.16	83.36	-
December	16.64	17.84	17.64	32.19	63.47	-

a/ ISA Daily price, fob and stowed Caribbean Port in bulk.
Source: International Sugar Organisation.

Mauritius: molasses sales
(t'000 tel quel)

End Table 5

	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81
Exports to:						
United Kingdom	36	105	115	135	169	126
USA	60	48	32	32	17	9
France	9	-	-	18	-	4
USSR	-	-	26	-	-	-
South Africa	-	-	-	-	-	11
Total Exports	105	153	173	185	186	150
Local sales and stock changes	24	47	22	16	21	N/A
Total	129	199	195	201	207	N/A

Source: Chamber of Agriculture.

APPENDIX 10

Mauritius: molasses prices End Table 6

	Ex-factory price (86° brix) Rs/t	fob price (tel quel) Rs/t
1971/72	70.05 a/	91.57
1972/73	90.39 b/	114.66
1973/74	214.17	254.69
1974/75	280.13	326.33
1975/76	177.89	222.08
1976/77	223.83	270.71
1977/78	146.16	200.68
1978/79	204.18	266.34
1979/80	380.41	490.00
1980/81	624.62	806.27

a/ At 86.14° brix.
b/ At 87.20° brix.
Source: Mauritius Molasses Company Limited.

Imports of molasses
(t'000)

End Table 7

	1970	1973	1978	1979	1980
North America	2 500	2 550	2 100	1 750	1 500
of which:					
USA	(2 300)	(2 325)	(1 750)	(1 400)	(1 175)
Western Europe	1 300	1 500	2 600	2 950	2 800
of which:					
Netherlands	(450)	(500)	(625)	(650)	(650)
UK	(475)	(500)	(550)	(625)	(600)
Far East	1 000	1 325	1 350	1 200	1 000
of which:					
Japan	(875)	(1 150)	(900)	(700)	(750)
Total	4 800	5 375	6 050	5 900	5 300

Source: United Molasses Company.

Mauritius: the potable alcohol market, 1979 — End Table 8

Company	Supply of ethanol from distilleries (£'000, 94° GL)	£'000s @ 40° GL	Bottles ('000, 40° GL)	Market share (%)
New Goodwill	2 332	5 480	7 307	89.5
Gilbey	237	557	743	9.1
OK Distillery	37	86	114	1.4
Total	2 606	6 123	8 164	100.0

Source: New Goodwill Limited and UNIDO team estimates.

Mauritius: production and use of ethanol (£'000 100° GL)

End Table 9

	1978	1979
Supply		
Stock at 1st January	612	911
Production	3 515	3 331
	4 127	4 242
Less stock at 31st December	911	1 024
Total supply	3 216	3 218
Utilisation for manufacture of ethanol products		
Rum	2 442	2 473
Refined spirits	168	115
Denatured spirits (for heating, lighting and other purposes)	285	283
Power alcohol	165	210
Vinegar	8	8
Perfumes and drugs	102	92
Production for export a/	16	20
	3 186	3 202
Loss due to evaporation	30	16
Total	3 216	3 218

a/ There were no exports in 1978 and only 30 200 £ in 1979.
Source: Chamber of Agriculture.

APPENDIX 10

EEC: imports of rum
('000 £)

End Table 10

	1977	1978	1979	1980
In bottles				
Germany	2 769	4 030	4 896	5 574
France	1 760	1 790	1 974	1 827
Italy	431	491	648	738
Netherlands	853	536	855	741
Belgium/Luxemburg	637	985	1 214	1 747
United Kingdom	141	789	868	559
Ireland	282	423	1 041	359
Denmark	682	399	428	473
Total	7 555	9 443	11 924	12 018
In bulk				
Germany	8 584	10 752	10 181	14 555
France	19 035	17 346	18 630	17 605
Italy	159	148	174	99
Netherlands	669	708	910	1 076
Belgium/Luxemburg	186	108	156	188
United Kingdom	15 399	20 339	23 267	23 000
Ireland	138	187	181	179
Denmark	162	123	123	146
Total	44 332	49 711	53 622	56 848

Source: NIMEXE

APPENDIX 11

FINANCIAL AND ECONOMIC ANALYSIS

CONTENTS

1. INTRODUCTION

1.01 This Appendix contains the financial projections of the two major projects, ethanol (Appendix 6A) and generation of electricity (Appendix 7A). The assumptions made in preparing the projections are stated.

General assumptions

1.02 No assumptions have been made about what organisations will own or operate which assets; these would be the subject of future feasibility studies. Projections have been made of the two operations as entities, rather than of the individual financial components. Inputs are from the outside world, and sales are direct to customers. There is therefore no need to calculate transfer prices of ethanol to the local oil companies, nor of bagasse or pellets to The Central Electricity Board (CEB). It is also assumed in the projections that bagasse itself has no cost. However, opportunity costs of bagasse are developed in para 7.11, Appendix 7A.

1.03 Costs are based on those at 1 July 1981. Exchange rates are those after the devaluation in October 1981

ie US $1 = Rs10.25
£1 = Rs19.00

The devaluation during report writing has made cost estimation particularly difficult. The foreign exchange components have been converted at the new rates. However, it is not possible to make accurate new estimates of all local costs, given that the devaluation would eventually affect some, but not all. For example the cost of steam in the sugar factories would probably not be affected, but that of electricity would increase to the extent that imported fuel is used to generate it.

1.04 Conversion rates in the other Appendices are historical,

ie	October 1979 - October 1981	US$1 = Rs8.67
	January 1977 - September 1979	US$1 = Rs6
	Sugar crop season 1979/80 (average)	US$1 = Rs7.335

Costs before 1977 have not been converted to dollars. The figures for Universal Board Company Limited in Appendix 8 are based on historical costs (and not converted to dollars) or on operating costs prepared by the liquidators and based on the July 1981 rate of US$1 = Rs8.67.

1.05 Unit costs before and after the 1981 devaluation are shown at Annex 1.

1.06 No account has been taken of taxation.

2. PROJECT COSTS

2.01 Proposed projects have been divided into two categories; their totals are as follows:

a) studies, technical assistance and pilot plants which could start immediately; also improvements to sugar factory process sections — Rs69 M ($6.7 M)

b) major investments which would depend on the outcome of the feasibility studies and the operation of the pilot plants, and for economic circumstances — Rs512 M ($50.0 M)

Details of the category (a) project costs are as follows:

Studies, technical assistance and pilot plants

	Reference	Foreign exchange component Rs'000	Foreign exchange component $'000	Local Costs Rs'000	Local Costs $'000	Total Rs'000	Total $'000
Livestock feeds	App 5						
Investigations into:							
utilisation of cane tops	7.10	213	(21.0)	226	(22.0)	439	(43.0)
utilisation of filter mud	7.10			219	(21.4)	219	(21.4)
treatment of bagasse	7.10	218	(21.3)	355	(34.6)	573	(55.9)
extraction of protein from sugarcane juice	7.10	888	(86.6)	398	(38.8)	1 286	(125.4)
Livestock production expert	7.10	1 540	(150.0)	-	-	1 540	(150.0)
		2 859	(278.9)	1 198	(116.8)	4 057	(395.7)
Fermentation and distillation products							
Pilot plant for anaerobic digestion of vinasse	App 6A/11.01	6 000	(590)	1 000	(90)	7 000	(680)
Technical assistance to distilleries	App 6B/2.08	72	(7)			72	(7)
		6 072	(597)	1 000	(90)	7 072	(687)
Energy from bagasse							
Improvements in process sections of 15 factories	App 7A/8.08	10 290	(1 000)	1 140	(100)	11 430	(1 100)
Feasibility study of pelleting bagasse	App 7A/7.15	640	(63)			640	(63)
Pilot pelleting plant at a sugar factory	App 7A/7.15	26 100	(2 550)	2 900	(280)	29 000	(2 830)
Feasibility study of charcoal plant	App 7B/1.21	384	(37)			384	(37)
Pilot charcoal plant	App 7B/1.21	14 760	(1 440)	1 640	(160)	16 400	(1 600)
		52 174	(5 090)	5 680	(540)	57 854	(5 630)
Fibre board	App 8						
Technical assistance to particle board factory	3.29	384	(37)			384	(37)
		61 489	(6 002.9)	7 878	(746.8)	69 367	(6 749.7)

2.02 Details of Category (b) project costs are:

Major Investments

	Reference	Foreign exchange component		Local Costs		Total	
		Rs M	$ M	Rs M	$ M	Rs M	$ M
Fermentation and distillation products	App 6A						
107 000 l/d ethanol distillation plant	6.30	90	(8.8)	32	(3.1)	122	(11.9)
Gasoline company works	2.10	2	(0.2)	1	(0.1)	3	(0.3)
(Vinasse digester, if needed)	4.58	24	(2.4)	3	(0.3)	27	(2.7)
		116	(11.4)	36	(3.5)	152	(14.9)
Energy	App 7A						
Equipping factories with pelleting plant	8.10	276	(27)	31	(3)	307	(30)
Establishment of 2 10 MW power stations	8.20	76	(7.4)	4	(0.4)	80	(7.8)
		352	(34.4)	35	(3.4)	387	(37.8)
Totals - without vinasse digester		444	(43.4)	68	(6.6)	512	(50.0)
- with vinasse digester		468	(45.8)	71	(6.9)	539	(52.7)

3. ETHANOL

Factors affecting returns

3.01 The likely viability of the present proposal depends on the predicted relationship between the prices of gasoline and molasses. This study has examined various possibilities of variations from July 1981 prices.

a) Gasoline and molasses prices will remain steady in real terms (ie no variation from July 1981 prices);

b) gasoline prices will rise 3%/y in real terms (this was a view held until recently by many development institutions, but see (d));

c) as gasoline prices rise in real terms, so production of ethanol from molasses will become increasingly economic, thus forcing up the price of molasses by an equal amount (ie each by 3%/y);

d) since petroleum prices are currently falling in real terms (and indeed at times in money terms) due to recession; and since consuming nations are (more or less) successfully pursuing policies of economy, energy conservation and the development of alternative energy sources, the pressure on prices of petroleum in real terms will not be felt until 1985 or maybe 1990;

e) following (b) and (d) there will come a time when the cost of petroleum, in relation to molasses, will have risen to such a level that the financial rate of return makes an ethanol plant an attractive proposition; and

f) molasses prices are so uncertain of prediction that it has been felt necessary to conduct sensitivity analyses on these. The price used in tabulations was $75/t fob Port Louis; sensitivities are calculated for $65 and $85/t. These represent input prices of Rs600, 509 and 690/t ($58.54, 49.66, 67.32) respectively (see Appendix 10, para 3.13).

Financial returns based on alternatives (a) and (c) above are as follows:

Option		IRR %	
		At current prices	Gasoline and molasses increasing at 3%/y
A	107 000 ℓ/d plant (Crop season only operation)	1.1	7.8
B	50 000 ℓ/d plant (Year round operation)	0	2.9
C	30 000 ℓ/d extension to Beau Plan	0	0

Financial returns

3.02 Financial returns on Option A on the various bases outlined in the previous paragraph and at a molasses price of Rs 600/t (except as noted in (c)) are as follows:

a)-d)	assume plant construction in 1982	
a)	constant 1981 prices	1.1
b)	gasoline prices rising 3%/y	14.0%
c)	gasoline and molasses prices rising 3%/y	7.8%
	- molasses price at Rs509/t	12.5%
	- molasses price at Rs690/t	2.0%
d)	gasoline and molasses prices rising 3%/y from 1985	5.9%
e)	as c), plant construction in 1990	12.5%

Financial projections based on alternative c) for the three options at a molasses price of Rs600/t are at End Tables 1-3.

Assumptions made

3.03 The projections make the following assumptions:

a) Construction costs would be paid in one year.

b) Production would start in year 2 at two-thirds capacity, and would reach full capacity in year 3.

c) Sales would be at the retail price of premium grade which effectively is its opportunity cost; there is also a saving in that the blend would be with regular grade, not premium grade, for sale at premium grade prices. All alcohol not used for blending would find an overseas market at the same price fob Port Louis.

d) Variable costs (which are detailed in Appendix 6A), including molasses, would be 15% higher per litre of alcohol in year 2, to take account of the likely early inefficiency of operation. This overrun is shown as a separate row in the projections.

e) The project life is 25 years, at the end of which there would be no residual value. No provisions for replacements have been made.

f) Contingencies of 10% have been added to capital plant costs (para 6.27, Appendix 6A), since these costs are based on quotations.

All remaining assumptions, including the pricing of ethanol are indicated in Appendix 6A, and the opportunity cost of molasses is derived in Appendix 10.

Analyses of other options

3.04 Anaerobic digestion of vinasse One of the technical assumptions made in Appendix 6A is that the distillery effluent, vinasse, would be disposed of on the sugarcane fields. This would depend on the location of the distillery, and an alternative method of disposal may be needed. Evaporation and incineration are not considered due to the high capital costs of the equipment. Anaerobic digestion of vinasse to produce methane has lower capital costs, and also a high ratio of energy output to input of 3.70 (compared to 1.77 for a distillery powered by sugar factory steam). However, since steam is cheap, the IRR on the investment in a vinasse digester would be rather low, at only 3.5%. It would of course be higher with Option B, where over half the methane would replace expensive fuel oil. The IRR on a 107 000 ℓ/d distillery with a vinasse digester would be 6.8%, compared with the base rate of 7.8%. End Table 4 is a projection of the cash movements of a 107 000 ℓ/d distillery with a vinasse digester.

3.05 Use of bagasse pellets in Option B If the pelletisation process described in Section 7 Appendix 7, is brought into use, it would be possible to replace fuel oil in the out-of-crop by bagasse pellets. This utilisation of pellets would amount to 7% of the total that could be produced. If the opportunity cost of the pellets is based on fuel oil, the IRR will of course be virtually unchanged. If it is based on coal, however, there would be a reduction in the cost of out-of-crop utilities. This raises the IRR of Option B under alternative (c) to 7.6%. This is slightly below the IRR of Option A, but takes no account of the electricity foregone by not burning the pellets in a power station.

4. ELECTRICITY

4.01 The financial analysis of electricity generation from bagasse is somewhat artificial for various reasons:

a) a complete analysis of CEB would be necessary to evaluate the rate of return on any particular option: this is beyond the terms of reference of the study;

b) the price of electricity sold would be determined by CEB, based on its overall production costs; and

c) as the complete operation is analysed, no opportunity cost for bagasse has been included, nor has it been necessary to calculate a transfer price for bagasse.

Since the principal purposes of the analysis are to compare the various options and to assess the viability of the pelletisation plant, these objections are not fatal. Given the purposes and the artificialities, no sensitivity analysis is carried out.

Financial returns

4.02 The financial returns of the options are:

	IRR %
Coal fired central power station	19.8
Using bagasse pellets:	
Option A - Central power station	21.3
Option B - Regional power station	22.6
Option C - Factory power stations	26.4

These results, using current electricity prices, show that a coal fired power station, or a bagasse fired one, would be highly profitable if used to generate the base load; however this conclusion takes no account of the resulting under-utilisation of CEB's other assets.

4.03 They also show that the returns on investments on a coal-fired and a bagasse fired central power station (Option A) are similar. The regional power stations (Option B) have a slightly higher return, for a small reduction in investment. The factory power stations (Option C) show a higher return because a large proportion of the investment has already been made in the sugar factories.

4.04 Options B and C produce less electricity than either Option A or the coal fired power station. Calculations of net present value (NPV) of the options confirm that Option C is preferred to the others as low as a 10% interest rate (although Option B then falls behind Option A). NPVs are as follows:

		NPV RsM	
		10%	15%
Coal fired central power station		380	134
Using bagasse pellets:	Option A	591	234
	Option B	577	246
	Option C	602	293

4.05 If the net cash forecasts of the central bagasse station and the regional power stations are compared with the central coal-fired station, it can be seen that the returns on the investments in the Woodex plants are quite high.

	IRR %
Option A vs coal-fired	23.6
Option B vs coal-fired	34.4

These results also highlight the superiority of Option B over Option A. Option C has only a very small incremental investment over the coal fired station, and the IRR accordingly is too high to measure, or to be meaningful.

Assumptions made

4.06 a) Construction costs are spread over three years.

b) Production would start in year 4, at two-thirds of capacity, and operate from year 5 at full capacity.

c) Sales are made at the price used elsewhere in this report of Rs0.96/kWh ($0.1).

d) Variable costs of bagasse pelleting, as with ethanol, would overrun by 15% in the first year of operation, Year 4. These costs are included in the row-headings in the projections.

e) The project life is 25 years. No residual value was used. Replacements at 5% of capital costs are included from year 8.

f) Contingencies are included in capital costs, which are first estimates.

All other assumptions made are detailed in Appendix 7A.

5. ECONOMIC ANALYSIS

5.01 Financial analyses of feasibility studies examine the projections of separate financial entities, whereas economic analyses are concerned with the effects of projects on a country's economy as a whole. In sector surveys such as the present study, it is usually inappropriate (or at least premature) to make assumptions about the ownership and financing of operating assets or about the relationships between the parties, especially of pricing. An obvious example is the assumption of a zero cost for bagasse where undoubtedly, if the factories were to produce electricity year-round, CEB would have to pay them a price for bagasse or for pellets or for electricity, which would include an element for the value of the bagasse. This would be for negotiation between the parties, the price falling in the range from zero to the opportunity costs of bagasse or pellets (para 7.10, Appendix 7A). The price agreed at this stage is not for prediction by consultants, nor are the ownership and operation of the assets; hence the projections of the ethanol and electricity projects consider the respective total systems, ie assuming purchases of equipment from and sales of products to the outside world.

5.02 These analyses therefore resemble economic ones. The principal difference is that prices are in financial terms, and have not been converted to economic "accounting" prices. The principal adjustments necessary are for foreign exchange, and for unskilled labour. The recommended cost conversion factors are respectively 1.1 (para 1.04, Appendix 12) and 0.7 (para 1.08, Appendix 12).

5.03 An important economic consideration for the Government is the possibility of changes in tax revenues resulting from the implementation of the projects. In the ethanol project it is reasonable to assume that excise duty would continue to be collected at the petrol pumps, and that the amount would not change as a result of the project; government would however forego export tax on molasses amounting to Rs5.3 M/y ($0.5 M) in July 1981 prices from year 3 onwards. Being a transfer payment, this does not affect the economic rate of return. (However, it is interesting to note that the financial return of 7.8% would fall to close to zero if this figure were included). The electricity project, on the other hand, would benefit government to the extent of increased taxation on sugar companies' profits arising from the use of a higher price than at present for electricity (or its bagassee or pellet equivalent); however this is also a transfer payment.

5.04 Secondary economic benefits have not been assessed and, although socially worthwhile, are probably not material in relation to the quantified returns. In the ethanol project these benefits would be limited to the jobs created and to the work done by fabrication companies (a significant proportion of total capital cost by comparison with the less developed countries). The recommended electricity project, Option C, may well create fewer jobs than other options; however, production of electricity at minimum cost gives maximum availability to all sectors of the economy, with major corresponding economic and social benefits.

5.05 The economic analyses of the projects are therefore concerned simply with using accounting prices of foreign exchange and of unskilled labour. Other assumptions are as detailed in the financial analyses. The effect on the ethanol project is small; both the output (gasoline substitute) and the major inputs (plant and molasses) have high proportions of foreign exchange costs. Little unskilled labour is used. The economic rankings are the same as the financial ones, and the economic return of Option A is slightly higher than the IRR, at 8.5%.

5.06 The inputs to the electricity project also have high foreign exchange components given a zero cost of bagasse. However, CEB's present electricity output has quite a low foreign component, and the increase in economic revenue over financial is therefore more limited than with the ethanol project. Consequently, with a low input of unskilled labour too, the economic rate of return is slightly lower than the IRR at 24.9% for Option C; again rankings are unaffected.

END TABLES

MAURITIUS

PROPOSED ETHANOL PLANT
107 000 l/d

(Rs '000)

	1	2	3	4	5
PRODUCTION L'000		8600	14300	14300	14300
MOLASSES USED T'000		38	57	57	57
REVENUE					
SALES - ETHANOL		32729	50216	51722	53274
- SAVING ON REGULAR		3560	5462	5625	5784
TOTAL SALES		36289	55677	57347	58068
COSTS					
MOLASSES		23484	36283	37371	38492
CHEMICALS		1306	1945	1945	1945
UTILITIES		2362	3518	3518	3518
TRANSPORT		317	472	472	472
FIRST YEAR OVERRUN		4120			
TOTAL VARIABLE COSTS		31588	42217	43306	44427
FIXED COSTS		5744	5744	5744	5744
GASOLINE CO COSTS		255	255	255	255
TOTAL COSTS		37587	48216	49305	50426
PROFIT/(LOSS)		-1298	7461	8043	8642
CAPITAL					
CAPITAL - DISTILLERY	122260				
GASOLINE COMPANIES	2860				
TOTAL CAPITAL	125220				
NET CASH MOVEMENT	-125220	-1298	7461	8043	8642

UNIT PRICES

PREMIUM	Rs/l	3.31
REGULAR	Rs/l	3.22
MOLASSES	Rs/t	600

UNIT COSTS - Rs/l ETHANOL

CHEMICALS	.136
UTILITIES - CROP	.246
TRANSPORT	.033

End Table 1

6	7	8	9	10
14300	14300	14300	14300	14300
57	57	57	57	57
54872	56518	58213	59960	61758
5968	6147	6331	6521	6717
60840	62665	64545	66481	68475
39647	40836	42061	43323	44623
1945	1945	1945	1945	1945
3518	3518	3518	3518	3518
472	472	472	472	472
45581	46771	47996	49258	50557
5744	5744	5744	5744	5744
255	255	255	255	255
51580	52770	53995	55257	56556
9259	9895	10550	11224	11919
9259	9895	10550	11224	11919

APPENDIX 11

End Table 2

APPENDIX 11

MAURITIUS

PROPOSED ETHANOL PLANT
50 000 l/d

(Rs '000)

	1	2	3	4	5	6	7	8	9	10
PRODUCTION L'000		10050	15000	15000	15000	15000	15000	15000	15000	15000
MOLASSES USED T'000		40	60	60	60	60	60	60	60	60
REVENUE										
SALES - ETHANOL		34263	52674	54254	55881	57558	59284	61063	62895	64782
- SAVING ON REGULAR		3727	5729	5901	6078	6260	6448	6641	6841	7046
TOTAL SALES		37990	58402	60155	61959	63818	65732	67704	69735	71827
COSTS										
MOLASSES		24658	38192	39338	40518	41734	42986	44275	45603	46972
CHEMICALS		1367	2040	2040	2040	2040	2040	2040	2040	2040
UTILITIES - CROP		1288	1924	1924	1924	1924	1924	1924	1924	1924
- OUT OF CROP		7475	11157	11157	11157	11157	11157	11157	11157	11157
TRANSPORT		332	495	495	495	495	495	495	495	495
FIRST YEAR OVERRUN		5268								
TOTAL VARIABLE COSTS		40389	53808	54954	56134	57350	58602	59891	61220	62588
FIXED COSTS		5265	5265	5265	5265	5265	5265	5265	5265	5265
GASOLINE CO COSTS		255	255	255	255	255	255	255	255	255
TOTAL COSTS		45909	59328	60474	61654	62870	64122	65411	66740	68108
PROFIT/(LOSS)		-7919	-926	-320	305	948	1611	2293	2996	3720
CAPITAL										
CAPITAL - DISTILLERY	81912									
GASOLINE COMPANIES	2960									
TOTAL CAPITAL	84872									
NET CASH MOVEMENT	-84872	-7919	-926	-320	305	948	1611	2293	2996	3720

UNIT PRICES

PREMIUM	Rs/l	3.31
REGULAR	Rs/l	3.22
MOLASSES	Rs/t	600

UNIT COSTS - Rs/l ETHANOL

CHEMICALS	.136
UTILITIES - CROP	.287
OUT OF CROP	1.345
TRANSPORT	.033

End Table 3

MAURITIUS

PROPOSED ETHANOL PLANT
30 000 1/d AT BEAU PLAN

(Rs '000)

		1	2	3	4	5	6	7	8	9	10
PRODUCTION	L'000		10080	15000	15000	15000	15000	15000	15000	15000	15000
MOLASSES USED	T'000		40	60	60	60	60	60	60	60	60
REVENUE											
SALES - ETHANOL			34366	52674	54254	55881	57558	58284	61063	62895	64782
- SAVING ON REGULAR			3738	5729	5901	6078	6260	6448	6641	6841	7048
TOTAL SALES			38103	58402	60155	61958	63818	65732	67704	69735	71827
POTABLE FOREGONE			4500	4500	4500	4500	4500	4500	4500	4500	4500
NET SALES			33603	53902	55655	57459	58318	61232	63204	65235	67327
COSTS											
MOLASSES			24658	38182	39338	40518	41734	42986	44275	45603	46972
CHEMICALS			1371	2040	2040	2040	2040	2040	2040	2040	2040
UTILITIES - CROP			1293	1924	1924	1924	1924	1924	1924	1924	1924
OUT OF CROP			7497	11157	11157	11157	11157	11157	11157	11157	11157
TRANSPORT			333	495	495	495	495	495	495	495	495
TOTAL VARIABLE COSTS			35152	53808	54954	56134	57350	58602	59891	61220	62588
FIXED COSTS			5265	5265	5265	5265	5265	5265	5265	5265	5265
GASOLINE CO COSTS			255	255	255	255	255	255	255	255	255
TOTAL COSTS			40672	59328	60474	61654	62870	64122	65411	66740	68108
PROFIT/(LOSS)			-7069	-5426	-4820	-4195	-3552	-2889	-2207	-1504	-780
CAPITAL											
CAPITAL - DISTILLERY		62435									
GASOLINE COMPANIES		2960									
TOTAL CAPITAL		65395									
NET CASH MOVEMENT		-65395	-7069	-5426	-4820	-4195	-3552	-2888	-2207	-1504	-780

UNIT PRICES

PREMIUM	Rs/l	3.31
REGULAR	Rs/l	3.22
MOLASSES	Rs/t	600
POTABLE ALCOHOL	Rs/l	7.50

UNIT COSTS - Rs/l ETHANOL

CHEMICALS	.136
UTILITIES - CROP	.287
OUT OF CROP	1.345
TRANSPORT	.033

APPENDIX 11

MAURITIUS

PROPOSED ETHANOL PLANT
107 000 l/d
WITH VINASSE DIGESTER

(Rs '000)

	1	2	3	4	5	6	7	8	9	10
PRODUCTION L'000		8600	14300	14300	14300	14300	14300	14300	14300	14300
MOLASSES USED T'000		38	57	57	57	57	57	57	57	57
REVENUE										
SALES - ETHANOL		32729	50216	51722	53274	54872	56518	58213	59960	61758
- SAVING ON REGULAR		3560	5462	5625	5794	5968	6147	6331	6521	6717
TOTAL SALES		36289	55677	57347	59068	60840	62665	64545	66481	68475
COSTS										
MOLASSES		23484	36283	37371	38492	39647	40836	42061	43323	44623
CHEMICALS		1306	1945	1945	1945	1945	1945	1945	1945	1945
UTILITIES		1690	2517	2517	2517	2517	2517	2517	2517	2517
TRANSPORT		317	472	472	472	472	472	472	472	472
FIRST YEAR OVERRUN		4018								
TOTAL VARIABLE COSTS		30815	41216	42305	43426	44580	45770	46995	48257	49556
FIXED COSTS		5744	5744	5744	5744	5744	5744	5744	5744	5744
GASOLINE CO COSTS		255	255	255	255	255	255	255	255	255
TOTAL COSTS		36814	47215	48304	49425	50579	51769	52994	54256	55555
PROFIT/(LOSS)		-525	8462	9044	9643	10260	10896	11551	12225	12920
CAPITAL										
CAPITAL - DISTILLERY	122260									
GASOLINE COMPANIES	2960									
VINASSE DIGESTER	27400									
TOTAL CAPITAL	152620									
NET CASH MOVEMENT	-152620	-525	8462	9044	9643	10260	10896	11551	12225	12920

UNIT PRICES

PREMIUM	Rs/l	3.31
REGULAR	Rs/l	3.22
MOLASSES	Rs/t	600

UNIT COSTS - Rs/l ETHANOL

CHEMICALS	.136
UTILITIES - CROP	.176
TRANSPORT	.033

End Table 5

MAURITIUS

PROPOSED CENTRAL
COAL FIRED POWER STATION

(Rs '000)

		1	2	3	4	5	6	7	8	9	10	11
SALES	GWH				152.900	229.364	229.364	229.364	229.364	229.364	229.364	229.364
COAL USED	T				97200	126777	126777	126777	126777	126777	126777	126777
REVENUE												
SALES					146784	220189	220189	220189	220189	220189	220189	220189
COST OF SALES												
COAL					60458	78855	78855	78855	78855	78855	78855	78855
ELEC GENERATION					11300	14800	14800	14800	14800	14800	14800	14800
TOTAL COST OF SALES					71758	93655	93655	93655	93655	93655	93655	93655
PROFIT					75026	126534	126534	126534	126534	126534	126534	126534
CAPITAL												
CENTRAL STATION		120000	170000	170000								
		120000	170000	170000								
REPLACEMENTS										6000	14500	23000
TOTAL CAPITAL		120000	170000	170000						6000	14500	23000
NET CASH MOVEMENT		-120000	-170000	-170000	75026	126534	126534	126534	126534	120534	112034	103534

APPENDIX 11

MAURITIUS

End Table 6

PROPOSED CENTRAL
BAGASSE PELLET POWER STATION

(Rs '000)

APPENDIX 11

	1	2	3	4	5	6	7	8	9	10	11
SALES GWH				152.900	229.364	229.364	229.364	229.364	229.364	229.364	229.364
PELLETS USED T				174300	227340	227340	227340	227340	227340	227340	227340
REVENUE											
SALES				146784	220189	220189	220189	220189	220189	220189	220189
COST OF SALES											
PROCESS SECTIONS				330	330	330	330	330	330	330	330
BAGASSE PELLETS				17450	22760	22760	22760	22760	22760	22760	22760
ELEC GENERATION				11500	11500	11500	11500	11500	11500	11500	11500
TOTAL COST OF SALES				29280	34590	34590	34590	34590	34590	34590	34590
PROFIT				117504	185599	185599	185599	185599	185599	185599	185599
CAPITAL											
CENTRAL STATION	50000	150000	150000								
PROCESS SECTIONS		5000	6430								
BAGASSE PELLETS		150000	157000								
	50000	305000	313430								
REPLACEMENTS									2500	17750	33421
TOTAL CAPITAL	50000	305000	313430						2500	17750	33421
NET CASH MOVEMENT	-50000	-305000	-313430	117504	185599	185599	185599	185599	183099	167849	152178

End Table 7

MAURITIUS

PROPOSED REGIONAL BAGASSE PELLET POWER STATIONS

(Rs '000)

		1	2	3	4	5	6	7	8	9	10	11
SALES	GWH				134.100	201.174	201.174	201.174	201.174	201.174	201.174	201.174
PELLETS USED	T				174300	227340	227340	227340	227340	227340	227340	227340
REVENUE												
SALES					128736	193127	193127	193127	193127	193127	193127	193127
COST OF SALES												
PROCESS SECTIONS					330	330	330	330	330	330	330	330
BAGASSE PELLETS					12917	16848	16848	16848	16848	16848	16848	16848
ELEC GENERATION					8200	8200	8200	8200	8200	8200	8200	8200
TOTAL COST OF SALES					21447	25378	25378	25378	25378	25378	25378	25378
PROFIT					107289	167749	167749	167749	167749	167749	167749	167749
CAPITAL												
PROCESS SECTIONS			5000	6430								
BAGASSE PELLETS			150000	157000								
ELEC GENERATION		80000	80000	80000								
		80000	235000	243430								
REPLACEMENTS										4000	15750	27921
TOTAL CAPITAL		80000	235000	243430						4000	15750	27921
NET CASH MOVEMENT		-80000	-235000	-243430	107289	167749	167749	167749	167749	163749	151999	139828

APPENDIX 11

End Table 8

MAURITIUS

PROPOSED FACTORY
BAGASSE PELLET POWER STATIONS

(Rs '000)

		1	2	3	4	5	6	7	8	9	10	11
SALES	GWH				121.300	182.017	182.017	182.017	182.017	182.017	182.017	182.017
PELLETS USED	T				174300	227340	227340	227340	227340	227340	227340	227340
REVENUE												
SALES					118448	174736	174736	174736	174736	174736	174736	174736
COST OF SALES												
PROCESS SECTIONS					330	330	330	330	330	330	330	330
BAGASSE PELLETS					12917	16848	16848	16848	16848	16848	16848	16848
ELEC GENERATION	1/				5100	5100	5100	5100	5100	5100	5100	5100
TOTAL COST OF SALES					18347	22278	22278	22278	22278	22278	22278	22278
PROFIT					98101	152458	152458	152458	152458	152458	152458	152458
CAPITAL												
PROCESS SECTIONS			5000	6430								
BAGASSE PELLETS			150000	157000								
ELEC GENERATION	2/	40000	40000	40000								
		40000	195000	203430								
REPLACEMENTS										2000	11750	21821
TOTAL CAPITAL		40000	195000	203430						2000	11750	21821
NET CASH MOVEMENT		-40000	-195000	-203430	98101	152458	152458	152458	152458	150458	140708	130537

ANNEX 1

UNIT COSTS BEFORE AND AFTER THE 1981 DEVALUATION

Unit costs before and after the 1981 devaluation

Annex 1

		Devaluation After	Devaluation Before	Foreign exchange before devaluation
Appendix 5				
Molasses ex-factory	Rs/t	600	502	100%
Soyabean meal	Rs/t	4 141	3 500	100%
Electricity	Rs/kWh	0.96	0.9	36%
Caustic soda	Rs/t	5 911	5 000	100%
Ammonia	Rs/t	3 025	2 560	100%
Steam	Rs/t	35	35	0
Urea	Rs/t	2 970	2 515	100%
Maize - imported	Rs/t	2 720	2 300	100%
- domestic	Rs/t	2 300	2 300	0
Cane tops	Rs/t	150	150	0
Cane tops treated	Rs/t	295	275	40%
Molasses	Rs/t	600	502	100%
Bagasse	Rs/t	126	100	100%
(See Appendix 7A below)				
Treated bagasse	Rs/t	271	2 500	47%
Cottonseed cake	Rs/t	3 074	2 600	100%
Leucaena	Rs/t	100	100	100%
Palm oil	Rs/t	5 125	4 335	100%
Dried poultry manure	Rs/t	266	266	0
Appendix 6A				
Gasoline - premium	Rs/ℓ	7.80	6.60	100%
- regular	Rs/ℓ	7.67	6.49	100%
Sulphuric acid 98%	Rs/t	7 890	6 675	100%
Ammonium sulphate	Rs/t	2 305	1 950	100%
Monoammonium phosphate	Rs/t	9 790	8 280	100%
Benzene	Rs/ℓ	[illegible]	4.1	100%
Denaturant, gasoline (transport only)	Rs/ℓ	0.33	0.30	50%
Steam	Rs/ℓ	35	35	0
Fuel oil	Rs/ℓ	3.56	3.01	100%
Water	Rs/m^3	0.1	0.1	0
Electricity	Rs/kWh	0.96	0.9	36%
Tankers	Rs'000	908	780	90%
Transport of ethanol	Rs/ℓ	0.33	0.30	50%
Transport	Rs/t molasses	33	30	50%
Other costs	Rs/t molasses	109	99	50%
Molasses ex-factory	Rs/t	600	502	100%
Molasses fob Port Louis	$/t	75	75	100%
Potable alcohol	Rs/ℓ	7.50	7.50	100%
Appendix 7A				
Transport of sugar	Rs/t km	1.61	1.46	50%
Coal	Rs/t	622	526	100%
Fuel oil	Rs/t	2.6	2.2	100%
Production of bagasse pellets	Rs/t	250	216	97%
Production of electricity	Rs/kWh			
Coal fired		0.708	0.608	99%
Bagasse pellets:				
Option A		0.589	0.51	98%
Option B		0.532	0.474	98%
Option C		0.441	0.385	97%
Selling price of electricity	Rs/kWh	0.96	0.9	36%
Opportunity cost of bagasse pellets a/	Rs/t			
vs coal		310 (126)	259 (104)	100%
vs oil Group IV		521 (212)	439 (176)	100%
Group V		600 (249)	506 (209)	100%
Group VI		675 (281)	559 (234)	100%
Appendix 8				
Delivery of bagasse to a pulp mill	Rs/t	220	200	50%
Bagasse ex-factory	Rs/t	100	100	0

a/ Unit costs in parentheses are for unpelleted bagasse.

ECONOMIC CONVERSION FACTORS

1.01 The economic analysis examines the project from the point of view of the national economy. In order to do this, certain adjustments need to be made to some of the costs and revenues given in the financial analyses.

1.02 One way would be to use the Little Mirrlees method, which involves converting the financial prices into economic or "accounting" prices using a series of "accounting" ratios (conversion factors). A series of these factors was calculated for Mauritius 1/ in 1972 for use in the evaluation of the Harbour Master Plan. These factors, with certain minor adjustments, were again used in 1973 for the evaluation of two projects - the Development of Water Supplies for Mauritius and the Northern Plains Irrigation Feasibility Study. Subsequently, however, these ratios have not been recalculated and could not be used without being completely updated.

1.03 Instead, the Ministry of Economic Planning and Development is using a simplified approach. Firstly, whenever possible border prices (that is cif or fob prices) are used. Since a high proportion of expenditure is on imports and a large proportion of output is exported, this approach is relatively straightforward in Mauritius.

1.04 The Mauritius rupee was devalued by 20% in early October 1981. The exchange rate is now effectively its market value. However, the rupee will continue to be under pressure for the following reasons:

a) the future outlook for world sugar prices is poor, and the terms of trade are expected to move against sugar;

b) as from the mid-1980s Mauritius will be moving into a difficult period of high debt servicing in terms of foreign exchange earnings; and

c) with the current recession the rate of commencement of new projects in the Export Processing Zone has fallen sharply. This in turn will lead to a slowing down in the growth of foreign exchange earnings from the Zone.

A shadow rate is applied to foreign exchange, using a conversion factor of 1.1.

1.05 Besides these adjustments, it is necessary to consider a shadow wage rate to be applied to unskilled labour (for skilled labour the market rate is used). A conversion

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1/ Scott, M F G (1972). Estimates of accounting prices for Mauritius.

factor of 0.4 was suggested for unskilled labour in 1972 and it was assumed that this would rise gradually through the 1970's as full employment was attained. A factor of 0.5 was used in 1973 in the analyses of the Water Development Project and the Northern Plains Irrigation Study.

1.06 Unemployment figures since 1972 are as follows:

1972 (June)	39 273
1973 (June)	28 716
1974 (May)	23 678
1975 (May)	22 024
1976 (May)	21 187
1977 (May)	18 059
1978 (May)	17 741
1979 (June)	22 953
1980 (June)	30 472
1981 (April)	53 048

Source: Ministry of Economic Planning and Development.

The total labour force in 1972 was estimated at 254 000, unemployment thus standing at 15%. Subsequently the level of unemployment fell and by the mid 1970's the labour market became tight, with a shortage of semi-skilled and skilled workers. By 1978, when the labour force was estimated at 301 000, unemployment was only 6%. However, with the recession, unemployment has once more risen and by 1981 again accounted for about 16% of the labour force.

1.07 Problems in recording both employment and unemployment in Mauritius mean that these figures are not necessarily comparable. They do, however, clearly indicate the general trends. In any event, unemployment in Mauritius is a complex phenomenon with the functioning of the labour market impeded by a variety of economic and sociological factors. For example, despite high unemployment, both the sugar industry and the manufacturing sector have been faced with problems of labour shortage.

1.08 Estimation of a shadow wage rate is complex, and is made more so by the fact that matters of political judgement by Government relating to employment policies are also involved. Certainly through the 1970's the shadow wage rate increased, as predicted until it could more or less be equated to the market rate. With the rise in unemployment this is no longer the case. Following discussions with the Ministry of Economic Planning and Development, it was therefore decided to take an intermediate point between Scott's original figure and the full market rate, and a conversion factor of 0.7 has been applied to unskilled labour.