OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

07490

Distr.
LIMITED

ID/WG.247/16
5 May 1977

ENGLISH

United Nations Industrial Development Organization

Joint UNEP/UNIDO Seminar on the Implication of Technology Choice in the African Sugar Industry,

Nairobi, Kenya, 18 - 22 April 1977

POSSIBILITIES FOR THE FURTHER PROCESSING OF SUGAR INDUSTRY BY-PRODUCTS[1]

by

F. Duguid and R. Alpine*

* Research Assistant and Senior Lecturer respectively, David Livingstone Institute, University of Strathclyde, Glasgow, Scotland, U.K.

1/ The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

id.77-1677

CONTENTS

Annex tables

INTRODUCTION

The by-products of the sugar industry - bagasse, molasses and filter mud - can each be used in a variety of ways as raw materials for further processing. Annex I shows the range of possibilities. The purpose of this paper, however, is to examine a few products which are most likely to be considered in African conditions.

The major use of bagasse is of course as a factory fuel and this is discussed in order to arrive at an economic price if it were to be used in another industry. The production of fibre board is examined based on the use of surplus bagasse. Molasses is commonly exported to Europe or North America where it may be used for the production of alcohol or as a constituent of cattle feed. At the same time the molasses-exporting country may import industrial alcohol. Typically in developing countries livestock production is important and the potential market for supplementary cattle feed, considerable. These two possibilities are examined in this paper. Filter mud is a minor by-product which is normally considered as a disposal problem. In most situations it is used as a fertilizer/soil conditioner but transport costs can be such that it is simply dumped or discharged to a waterway.

The output of each of the by-products depends on the technology and the length of crushing season. Annex II gives the tonnages of each at four scales of operation in the long and short seasons. The quantities have been calculated as percentages of the total tonnage of cane crushed per annum. In the large-scale, vacuum pan technology the values are 30% on cane for wet bagasse, 3.5% molasses and 5% filter mud. In the small-scale open pan technology these are 35%, 4.25% and 4% respectively.

The quantities of materials potentially available for further processing obviously determines the maximum scale of production. At any given crushing capacity the season length has a significant effect on the daily capacity of the secondary industry if it is assumed that it would operate for say 300 days per year. For example 200 tch in the long season produces 36,288 t molasses or about 120 t/day for 300 days with 4 months storage. In the short season, however only 67 t would be available each day (to meet 300 days operation) and storage would be needed for 8 months supply.

If economies of scale exist in a processing industry, the average costs of production will decrease with scale. While the availability of the raw material determines how much advantage can be taken of economies of scale the limiting factor may in fact be market size for a given product. If this were lower than the potential scale of production, costs will be increased, in which case the question of competition with imports arises. Economic viability will depend on the ability of the local product to compete in price and quality with the imported product, unless the industry is protected by Government.

I. BAGASSE

A. Characteristics

Bagasse is the cane fibre remaining after the extraction of juice, with a composition of 43-52% fibre, 46-52% moisture and 2-6% soluble solids. The composition is affected by efficiency of milling, cane variety and maturity, and cane deterioration since harvesting. Production of wet bagasse is assumed to be 30% in the large-scale technology from a cane of 15% fibre. In the small-scale, largely due to the difference in milling efficiency, production is taken to be 35% on cane, With a low bulk density of around 160 kg/m^3 and the inflammable nature of the material bagasse is a very costly material to transport and store.

B. Factory fuel and value

The most natural use for bagasse is as boiler fuel to power the sugar factory, or heat the furnaces in the case of an OPS unit. Unless the cane fibre is very low an efficient vacuum pan factory should be virtually self-sufficient in fuel, and discussion of potential uses for bagasse implies that either an alternative fuel has to be provided or that the quality of bagasse available is surplus to factory requirements. In fact surplus bagasse is likely only in the case of the vacuum pan factories as the OPS units have to use relatively large amounts of supplementary fuels - see paper (1)- for example firewood at ₪12/t.

In terms of fuel value, 1 tonne of furnace oil could replace about 5 tonnes of bagasse. At a price of ₪0.12/litre for furnace oil the factory price for wet bagasse with no allowance for baling or transport could be taken as ₪22.32/tonne. In order to substitute bagasse with another fuel an additional cost of boiler conversion would be probably be incurred. However to utilize a surplus quantity of bagasse the additional costs would be mainly for baling and storage. Transport costs can be excluded if it is assumed that the further processing takes place on the same site as the sugar factory.

An approximation of the cost of de-pithing and baling is made using data from Paturau (2) based on 1968 prices. In the cases of 30,000 t per annum of surplus bagasse this cost is shown to be (0.91+2.50 Y+Z) £ per tonne, where Y is labour cost per hour and Z is the cost of depithing per tonne of wet bagasse. Unskilled labour at sugar factories costs around £1 per day at low wage rates. Paturau quotes depithing costs (for fairly simple dry or humid depithing to extract about 20% of pith) at £0.75 per tonne of bone dry fibre produced; equivalent to £0.35 per tonne of wet bagasse treated. This figure he argues would not vary between countries since the operation is largely automated. When allowance is made for inflation between 1968 and 1976, and for the smaller scale of operation being considered (at most 15,000 t bagasse per annum) it is likely that the cost per tonne of wet baled, depithed bagasse would be at least £3/tonne.

Therefore a realistic value for wet bagasse for further processing is assumed to be £25.50/tonne.

C. Fibre board production

The fibre proportion of bagasse (approximately 48%) includes true fibre and pith in the ratio 5:2 by weight. The properties of the true fibres are such as to ensure close bonding, giving strength and cohesiveness. On the other hand the pith cells do not bond together and therefore weaken any pulp containing them. For this reason bagasse is normally depithed beforehand. The pith can be used in the factory boilers.

The process involved is relatively simple with digestion of the fibre using steam followed by washing, screening and the addition of resin (80 kg/tonne board). The forming stage can be altered to produce board of various thickness depending on its end use. It is also possible to treat the board for specific purposes for example for insulation by the addition of alum or for roofing by impregnation with asphalt and surface coating with aluminium paint (3).

Each tonne of fibre board is produced from 3 tonnes of wet bagasse. Using the output figures in Annex II and by assuming the utilisation of a 5% surplus of bagasse, the quantities available are about 7,750 t and 15,500 t in the 100 and 200 tch long season respectively and 4,300 t and 8,600 t in the short season. The largest quantity (from 200 tch, long season) would provide about 51 t/day wet bagasse or 17 t/d board when operating 300 days per year.

At 1968 prices, Paturau (2) estimates the capital cost of plant and equipment including depithing, building and services as £2 m. The increase in cost between 1968 and 1976 is assumed to be 80% after the prices of exported manufactured goods in the UN Monthly Bulletin of Statistics thus capital cost is £3.6 m. Other inputs are 80 kg resin/tonne board or 408 t per annum and electricity at a rate of 200 kwh per tonne board. Pith up to 10 t/day can be used in the boilers for the generation of steam. It should be possible, during the crushing season, for the board factory to be supplied with power from the sugar factory. Repairs and maintenance expenditure is estimated at 2% of capital costs and miscellaneous expenses at 5% of production costs.

Annex III contains fuller details, showing unit operating costs per tonne of board to be £55: depreciation at 5% p.a. would add a further £35 to this figure. Employment in the production of fibre board is typical of a semi-automated process with a few senior management, engineers and supervisors and a larger number of unskilled labour mostly employed in the handling of the finished product.

II. MOLASSES

A. Characteristics

Final or blackstrap molasses is the liquid remaining after repeated crystallisation and centrifugal separation of sugar. Molasses commonly contains 30-40% sucrose which cannot be recovered by crystallization. Total production is assumed to be 3.5% on cane in the vacuum pan factory and 4.25% in the open pan. The latter will also have a higher sucrose content due to the lower efficiency of the crystallisation process. Molasses also contains much of the nutrient elements, vitamins etc. from the sugar cane. It is commonly exported but may be dumped, sprayed as a road binder or added to irrigation water as ways of disposal.

B. Value as export

The exfactory price for molasses has been assumed as $15 tonne and $30/tonne. In practice the price paid varies considerably depending on the use of the molasses, local or export; for example a local buyer may pay more or less than the export price depending on the type of sale, quantity involved etc. The export price could also be affected by Government subsidy, or by the influence of shadow foreign exchange rates.

C. Alcohol production

The sugar-rich molasses can be used as a raw material in the production of a wide range of alcohols (potable and industrial), acids and yeasts. The fermentation process is carried out in large open or closed vats where a mixture of diluted molasses, essential nutrients and acid is subject to the anaerobic action of a yeast, bacteria or mould culture; yeast is the most common producing ethyl alcohol (ethanol) and carbon dioxide.

To increase the output of ethyl alcohol from about 46% by weight in the fermented mash, distillation is carried out followed by purification in a fractionating column. The final product is industrial alcohol (96° GL) and is commonly used as a solvent or for further processing, possibly in competition with oil - based products. Ethyl alcohol can also be used as a fuel for heating, lighting or power (anhydrous alcohol can be added to petrol as it has an octane rating of 115, thus reducing the total domestic consumption of petroleum).

To prevent the illegal use or accidental consumption of the colourless alcohol, it is common to denature the spirit by adding pyridene and methyl violet. Crude 'potable' alcohol may be diluted and flavoured industrial alcohol but a true potable spirit for the market requires further purification.

From Annex II, the maximum production of molasses is 36,288 from the 200 tch, long season. This is assumed to be 80° Brix and containing about 50% total fermentable sugars. A typical yield of alcohol is 50-55 litres per 100 kg fermentable sugar; a ratio of 1 tonne alcohol per 5 tonnes of molasses is used in the calculations in Annex IV. The output of alcohol is in the region of 30,000 litres/day. The 100 tch, long season therefore, has a potential output of about 15,000 litres/day as does the 200 tch, short season. The calculations also assume that the distillery is situated beside the sugar factory in order to share facilities such as steam when available and maintenance at a charge of 5% of production costs.

The revenue from the sale of alcohol is based on a price of $300/t. Assuming 25 years of full production the 30,000 l distillery has an IRR of 15% (NPV @ 10% of $2.17 million) while the 15,000 l distillery has an IRR of only 7% (NPV of - $0.76 million). However, if the opportunity cost of molasses is raised to a level of $30/t with all else unchanged the NPV of the larger distillery falls to - $2.73 m or an IRR of 2%. Alternatively the selling prices of alcohol would have to be raised to $340/t to provide the 30,000 l distillery with 10% rate of return when paying $30/t for molasses.

A by-product of the fermentation process is carbon dioxide, which can be collected if fermentation takes place in closed vats. CO_2 is produced at a rate of about 16 kg per 100 kg molasses of which 11-12 kg may be recovered (see reference (4)).

Liquified CO_2 can be sold at around $160/t. The mainly automated process would probably employ 1 skilled/semi-skilled supervisor and a few unskilled labourers for handling the 20 kg bottles of gas. This gas is commonly used in beverages (a 20 kg cylinder will be used for 5,000 small soft drinks bottles). The liquified gas can also be further compressed to dry ice

D. Cattle feed production

Molasses is a supplier of energy and can form part of a balanced feed ration when supplemented with measured quantities of minerals, vitamins and non-protein nitrogen (urea) Being a very palatable feed which also stimulates appetite it can be used in order to increase the consumption of locally available poor quality fodder such as cobs or hay. For ease of transport, storage and feeding the liquid molasses-based feed can be mixed with a proportion of absorbent solids such as bagasse, pith or sawdust. By obviating the need for expensive tins or drums, the costs of production and hence price to the small farmer should be considerably reduced.

A carefully managed feedlot system for the fattening of beef cattle can successfully feed relatively large quantities of molasses (e.g. 7.5 kg/head/day for six months) without significant mortality levels due to scouring (caused by high potash levels) or bloating. Liveweight gains of over 0.5 kg/day have been achieved with profits of over 25% using local unimproved stock.

Recommended daily intakes for cattle on small holdings are much lower (maximum of 2 kg/head/day). Feed is usually used for beef production but special rations can be made for dairy animals.

A typical composition of a feedlot mixture would be 75% molasses; 21% water; 4% urea; 0.001% vitamin and mineral mix; a trace of Vit A concentrate. (A dairy mixture would include 0.01% phosphoric acid). The supplements to the feed are normally imported and may account for over ½ of the total cost.

The capital costs are relatively small mainly being mixing and storage tanks. A unit mixing batches of 25 t would cost in the region of $50,000. More simply however, if molasses can be bought from the factory in small quantities the constituents can be mixed by hand in buckets or small tanks for daily use.

The production of solid feed would entail the addition of say 10% sawdust and compression into blocks. The economics of this type of production would depend on the availability of a local supply of the absorbent material.

III. FILTER MUD

Filter mud contains the non-sucrose components of sugar cane juice, both organic and inorganic, which are precipitated out of the juice in the settling/clarification process. Mud is normally 60-80% moisture depending on the type of filter used and amounts to 4-5% on cane.

On a dry basis filter mud contains 1-4% CaO; 1-3% P_2O_5 and 0.5-1.5% MgO. It is commonly spread on the fields as a fertilizer/soil conditioner but rarely on a scientific basis. The slight fertilizing effect, especially phosphate, is due to the very large quantities applied between uprooting and replanting or occassionaly on the ratoon crop. Mud may contain up to 30% fibre and as such has a beneficial effect for example, on heavy clay soils as a form of organic manure.

The major problem with filter mud is the cost of transport for its disposal. In the vacuum pan factory it is produced at a rate of 240 t/day and in the open pan factory 4 t/day. Where an outgrower system is involved particularly on the small-scale, the factory would give away the mud or sell at a very low price to cane farmers who collect and load the material themselves.

In the case of Egypt, filter mud is allowed to flow directly into the River Nile. With production of 3-400 t per day from each factory and the cane being grown in small scattered plots, transport costs are prohibitive. The situation is tolerable however, due to the sheer magnitude of the river and its minimum rate of flow during the crushing season.

Filter mud can be used for the extraction of cane wax which coated the cane stalks before crushing. The crude wax consists of a mixture of wax and fatty lipids which can be separated to produce hard wax and fats. The processes are carried out with aid of solvents which can be recovered and re-used. The hard wax compares favourably with other vegetable waxes and the soft wax is a source of sterols. The extraction of wax is about 10% leaving 90% by weight to be disposed of as before.

IV. CONCLUSIONS

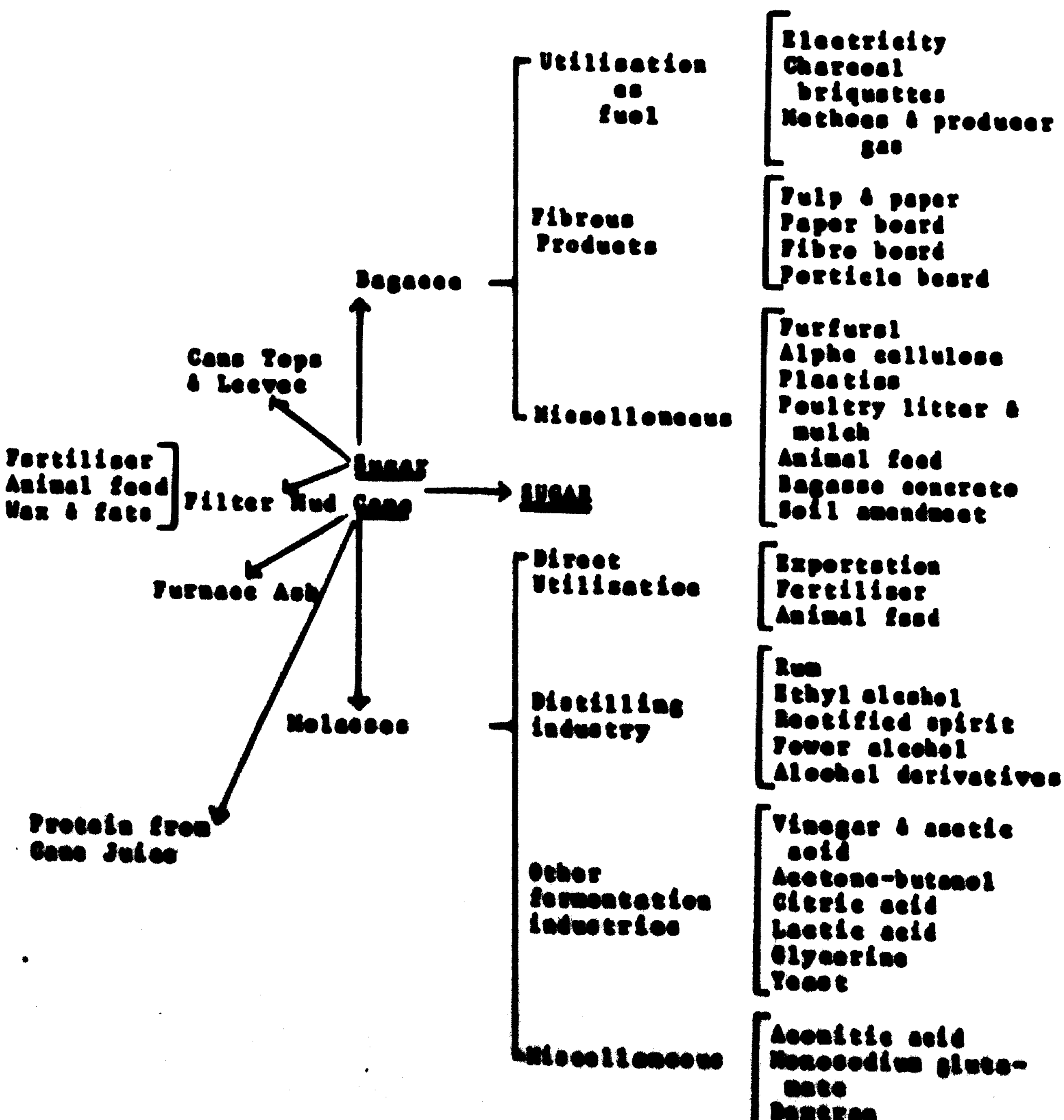
The secondary processing of cane sugar by-products tend to be such that the scale of operation is important in determining viability, while the current market size may not warrant that scale. Although the range of products is wide, the demand for each is very small in most developing countries and some degree of protection would probably be required against imports.

In most cases, the actual process tends to be rather capital-intensive and automated requiring a considerable level of skill but few people. This also implies a large proportion of imported capital goods.

This paper has tried to emphasise, those secondary industries with greatest potential and application in current African conditions. The technologies involved in fibreboard, alcohol and cattle feed production are relatively simple so that much of the capital goods could be manufactured locally. The products also have wide application in developing countries for example in low-cost housing hospitals and livestock improvement programmes respectively.

ANNEX I

By-Products of the Cane Sugar Industry



Source: Paturau J.M., By-Products of the Cane Sugar Industry, Elsevier, Amsterdam, 1969.

ANNEX II

Output (tonnes) of cane sugar by-products at various scales of operation

	Bagasse (wet)	Molasses	Filter Mud
Long season			
100 tch (V.P.)	155,520	18,144	25,920
200 tch (V.P.)	311,040	36,288	51,840
100 tcd (OPS)	7,070	858	808
150 tcd (OPS)	10,605	1,288	1,212
Short season			
100 tch (V.P.)	86,400	10,080	14,400
200 tch (V.P.)	172,800	20,160	28,800
100 tcd (OPS)	3,920	476	448
150 tcd (OPS)	5,880	714	672

Note: Production of bagasse, molasses and filter mud is assumed to be 30 per cent on cane; 3.5 per cent and 5 per cent respectively in the vacuum pan factory and 35 per cent on cane; 4.25 per cent and 4 per cent in the open pan factory

ANNEX III

Factory capital cost $3.6 m

Factory operating costs per tonne board

Fuel 200 KWh @ $0.02/KWh
= $4

Resin 80 Kg @ $100/t
= $8

Bagasse 3 t @ $3/t
= $9

Repairs and replacement materials @ 2 per cent of installed factory cost = $72,000

= $14/tonne board

Miscellaneous expenditure @ 5 per cent of production costs = $1

Employment

Senior Management	1 @ $1200/month
Other managerial	2 @ $1000
Supervisory staff	11 @ $ 230
Skilled labour	3 @ $ 125
Unskilled	65 @ $ 28.5

Total cost of salaries and wages $8177.5/month

= $98,130 p.a.

Working capital, 3 months production

= $45,900 (materials) + $24,532 (wages)

= $70,432

Unit costs/tonne board = $36 (materials) + $19 (labour) + $35 (5 per cent depreciation) = $90/t

ANNEX IV

Factory capital costs, 1976, $m

	30,000l/d	15,000l/d
Capital	2.40	1.68
CIF, erection etc.	1.60	1.12
	4.00	2.80
Local costs	0.40	0.28
	4.40	3.08

Factory operating costs, $m

Item	Unit Cost	30,000l/d	15,000l/d
Molasses	$15/t	0.54	0.27
Oil+	$130/t	0.10	0.05
Sulphuric Acid+	$300/t	0.11	0.05
Nutrients+		0.03	0.02
Electricity+	$0.02/unit	0.05	0.03
Standing Charge		0.02	0.01
Maintenance	2%	0.09	0.06
Staff & Labour		0.11	0.10
Charge from sugar factory	5%	0.06	0.04
Miscellaneous	5%	0.06	0.03
		1.17	0.66

\+ Oil @ 2.5t/day
Sulphuric acid @ 1.2t/day
Nutrients @ 0.15 t ammonium phosphate and 0.5 t ammonium sulphate/day
Electricity @ 7500 KWh/day
Each of these is halved for the 15,000l/d factory.

ANNEX IV (Cont/d.)

Employment*

Senior managerial	1 @ $1200/month
Superintendent	3 @ $1000
Accountant	2 @ $ 800
Clerical	6 @ $ 90
Skilled labour	16 @ $ 125
Semi-skilled	6 @ $ 45
Unskilled	16 @ $28.5

* The figures given are for the 30,000 l/d scale of production. For 15,000 l/d, there would be 1 clerical, 2 skilled and 2 unskilled people less.

Working Capital, 3 months production plus 3 months stores of raw materials (excluding molasses, including maintenance

= $0.54 m (production) + $0.08 m (stores)

= $0.62 m @ 30,000 l/d

or $0.27 m + $0.05 m = $0.32 m @ 15,000 l/d

Replacement expenditure

5 per cent of $4 m (capital cost) from the years 5-24

= $0.20 m/yr.

Revenue

7,200 t alcohol @ $300/t = $2.16 m (30,000 l/d)

3,600 t alcohol @ $300/t = $1.08 m (15,000 l/d)

ANNEX IV (cont/d.)

Net Revenue	30,000l/d	15,000l/d
Sales Revenue	2.16	1.08
Operating Costs	1.17	0.66
Replacement	0.20	0.14
	0.79	0.28

Net Present Values @ 10%	$2.17 million	-$0.76 million
Internal Rate of Return	15%	7%

REFERENCES

1. Duguid Fiona and Alpine R., Energy Consumption in the Sugar Industry, paper presented at the UNEP/UNIDO Seminar on the Implication of Technology Choice in the African Sugar Industry, 18-22 April 1977, Nairobi, Kenya.

2. Paturau J.M., By-Products of the Cane Sugar Industry, Elsevier, Amsterdam, 1969.

3. Rao A.V.R., Roofing with Low-Cost Corrugated Asphalt Sheets, *Appropriate Technology*, Vol.1, No.4, 1974.

4. Rater P., Molasses Utilisation, Agricultural Services Bulletin No.25, FAO, Rome, 1975.

B-322

77.09.16