Joint UNDP/World Bank Energy Sector Management Assistance Program

Activity Completion Report

No. 063/86

Country: ETHIOPIA

Activity: BAGASSE ENERGY SURVEY

DECEMBER 1986

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

The Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP), started in April 1983, assists countries in implementing the main investment and policy recommendations of the Energy Sector Assessment Reports produced under another Joint UNDP/World Bank Program. ESMAP provides staff and consultant assistance in formulating and justifying priority pre-investment and investment projects and in providing management, institutional and policy support. The reports produced under this Program provide governments, donors and potential investors with the information needed to speed up project preparation and implementation. ESMAP activities can be classified broadly into three groups:

- Energy Assessment Status Reports: these evaluate achievements in the year following issuance of the original assessment report and point out where urgent action is still needed;

- Project Formulation and Justification: work designed to accelerate the preparation and implementation of investment projects; and

- Institutional and Policy Support: this work also frequently leads to the identification of technical assistance packages.

The Program aims to supplement, advance and strengthen the impact of bilateral and multilateral resources already available for technical assistance in the energy sector.

Funding of the Program

The Program is a major international effort and, while the core finance has been provided by the UNDP and the World Bank, important financial contributions to the Program have also been made by a number of bilateral agencies. Countries which have now made or pledged initial contributions to the programs through the UNDP Energy Account, or through other cost-sharing arrangements with UNDP, are the Netherlands, Sweden, Australia, Switzerland, Finland, United Kingdom, Denmark, Norway, and New Zealand.

Further Information

For further information on the Program or to obtain copies of completed ESMAP reports, which are listed at the end of this document, please contact:

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ETHIOPIA

BAGASSE ENERGY SURVEY

DECEMBER 1986

This work is based on the findings of an ESMAP mission which visited Ethiopia in January 1985. The mission members included Messrs. Ernesto Terrado (Mission Leader, World Bank), Josef Leitmann (Energy economist, World Bank), Norland Suzor (Bagasse Energy Specialist), Felix Adam (Sugar Engineering Specialist) and Hans Peter Buess (Briquetting Specialist). Messrs. Terrado, Leitmann, and Suzor prepared the final report.

ABBREVIATIONS

Br	Ethiopian Birr
ERR	Economic Rate of Return
FRR	Financial Rate of Return
GJ	Gigajoule
GWh	Gigawatt hour
HHV	Higher heating value
kg	kilogram
kW	kilowatt
kWh	kilowatt hour
l	liter
m.c.	moisture content, wet basis
MCR	Maximum Capacity Rating
MJ	Megajoule
NCV	Net calorific value
PRV	Pressure release valve
t.c.	metric tons of cane
TCD	metric tons of cane per day
t.c.h.	metric tons of cane per hour
TOE	tonn f oil equivalent

ECAFCO	Ethiopian Chipwood and Furniture Corporation
EELPA	Ethiopian Electric Light and Power Authority
EPPSC	Ethiopian Pulp and Paper Share Corporation
ESC	Ethiopian Sugar Corporation
ESMAP	Joint UNDP/World Bank Energy Sector Management Assistance Program

EQUIVALENCIES

Currency: US$1.00 = Br. 2.07
Br. 1.00 = US$0.48

Energy units: 1 MJ = 948 Btu
= 239 kcal
= 0.278 kWh

Bagasse:

m.c. (%)	HHV MJ/kg	NCV MJ/kg
50	9.71	7.38
35	12.54	10.35
10	17.12	15.30

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EXECUTIVE SUMMARY

1. The key energy problem facing the overwhelming majority of Ethiopia's population is the increasing scarcity and cost of traditional household fuels, which account for over 90% of national energy consumption. Afforestation programs are urgently needed but will not be able to redress the imbalance between supply and demand in the short-run. Thus, there is an immediate need to develop and utilize indigenous fuel substitutes. The production, processing and marketing of densified bagasse (milled sugar cane waste) were identified as priority objectives for fuelwood substitution in the recent Ethiopia Energy Assessment. 1/

2. Ethiopia has a well-developed sugar industry consisting of three mills which currently process about 1,640,000 metric tons of cane, produce 186,000 tons of sugar, and yield 18,000 tons of bone dry excess bagasse annually, of which 4000 tonnes are not presently being used. In January, 1985, a mission from the joint UNDP/World Bank Energy Sector Management Assistance Program visited Ethiopia to identify opportunities for increasing and utilizing surplus bagasse for both energy and other uses. Besides household fuel use, the mission considered bagasse's potential as a pulp substitute in the paper industry, an input in the manufacture of particle board, an industrial solid fuel and a source of surplus electricity generation from the sugar mills.

3. After a detailed engineering analysis, the mission found that 115,000 metric tons (bone dry) of net excess bagasse could be generated industry-wide, once investments in certain mill modifications had been made. These consist of improvements in factory steam utilization (yielding 39,000 tons), more efficient boiler operation by pre-drying bagasse (54,000 tons), and savings of bagasse from burning particles captured in the drying process (22,000 tons). Of this surplus, 13,000 tons would go for factory use, leaving the remainder (102,000 tons) for energy substitution or other economic purposes. All of the recommended factory modifications have been tried and proven successful in several sugar factories in other countries. The burning of cane leaves and tops in place of bagasse was also contemplated; conservatively, this would yield 86,000 tons of net excess bagasse. However, more research is needed on this option before it can be adopted.

4. In the immediate future, for reasons of the timing of investments in alternative uses, their priority and economic return, the optimal end-use for surplus bagasse is as a densified fuel substitute for households and industry. Densified bagasse appears to be an economically

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1/ Ethiopia: Issues and Options in the Energy Sector (Report 4741-ET), Joint UNDP/World Bank Energy Sector Assessment Program, July 1984.

and financially attractive substitute for household and industrial fuel use in Ethiopia, especially given the scarcity of domestic forest reserves.

Table 1: DENSIFIED BAGASSE AS FUEL: FINANCIAL AND ECONOMIC COST COMPARISON

	Delivered Price	- Cost of Useful Energy - a/ Household	Industrial
	($/tonne)	- - - - - ($/GJ) - - - - -	
Financial Costs:			
Densified Bagasse	67.00	13.47	5.21
Fuelwood	83.25	18.60	9.86
Charcoal	362.00-434.97	45.80 a/	14.69 a/
Fuel Oil ($/l)	0.29	--	8.51
Electricity ($/kWh)	0.03	--	8.72
Economic Costs:			
Densified Bagasse	81.80	16.45	6.36
Kerosene ($/l)	0.40	30.19	--
Charcoal	434.97	50.00	18.75
Fuel Oil ($/l)	0.27	--	7.92
Electricity ($/kWh)	0.06	--	17.54

a/ Incorporates conversion efficiencies for each fuel in household stoves or industrial boilers.

b/ Average.

5. If, after the planned expansion of Ethiopia's paper plant, a pulping plant is constructed at the papermaking facility in 1991/1992, it will be possible to use 29-39,000 tons (bone dry) of bagasse to produce 15-20,000 tons of pulp, thus saving an estimated US$7-9 million p.a. in foreign exchange. If a depithing facility were installed for pulp production, 4250 tons (bone dry) of bagasse could also be used to substitute for 6000 cubic meters of scarce eucalyptus now being consumed by the particle board industry. These options should be evaluated if the planned expansion of the paper plant materializes. Alternatively, densified bagasse could be used to generate year-round surplus power at the sugar mills for supply to the national grid amounting to 150 GWh. However, given the current tariff structure and hydropower surplus, this is not an immediately viable option; in the medium term, though, the potential will exist for selling peak power to the grid.

6. Given this current prioritization of end-uses, overall project objectives were defined as: (a) maximizing surplus bagasse through decreased factory steam consumption and pre-drying bagasse with flue gases; and (b) densifying these surpluses to produce a fuelwood substitute. The project is defined in two phases, the initial period for testing and feasibility work and the subsequent phase for implementing

actual factory modifications. Phase I involves two components: (a) the installation, operation and evaluation of a pilot bagasse briquetting plant; and (b) the preparation of feasibility studies to gauge the market acceptability of briquettes, evaluate the use of cane tops as supplemental fuel, and design mill improvements to increase bagasse output. Phase II consists of preparing final design and tender documents and implementing essential factory improvements. This scheduling is recommended so that a sound project can be developed in Phase II by drawing on important results obtained during the first phase.

7. If fully implemented, the two phases of the project will cost an estimated $12.2 million, consisting of $10.1 million in foreign and $2.1 million in local costs (see Table 2). With physical and price contingencies, their total cost would amount to $14.9 million. The project has a financial rate of return of 31%, based on the market price of substantial fuelwood, and when completely operational, will generate $4.2 million yearly in net financial benefits. The economic rate of return is more difficult to estimate because of the unknown economic value of fuelwood. If, instead, imported fuel oil or kerosene is used as the base fuel the proposed project would have a nominal economic rate of return of about 48% when the entire production is assumed to displace fuel oil in industry, and about 90% when displacing kerosene in household use. Project risks are considered minimal, given the competent management of Ethiopia's sugar mills and the country's desperate fuelwood situation.

Table 2: FOREIGN AND LOCAL INVESTMENT COSTS FOR PHASES I AND II OF BAGASSE PROJECT

	Foreign	Local	Total
		(x US$1000)	
Phase I:			
Design/Tender	56.00	6.00	62.00
Equipment	455.00	60.00	515.00
Evaluations	25.00	10.00	35.00
Subtotal	536.00	76.00	612.00
Phase II:			
Feasibility study	220.00	16.00	236.00
Design/Tender	390.00	30.00	420.00
Surplus bagasse generation equipment	1,061.14	312.68	1,373.82
Drying system	4,256.32	979.95	5,236.27
Densification system	3,202.00	576.00	3,778.00
Bagasse reclaim system	455.84	104.16	560.00
Subtotal	9,585.30	2,018.79	11,604.09
TOTAL	10,121.30	2,094.79	12,216.09

I. BACKGROUND AND OBJECTIVES

Country Situation

1.1 Ethiopia's economy faces a difficult challenge in the 1980s and beyond, having begun to recover from the recent drought which had devastating effects on all sectors of the economy. The external current account deficit continues to widen; since 1981/82 the value of merchandise imports has been running at double the value of merchandise exports. In the energy sector, the cost of petroleum imports is an enormous burden, amounting to about half of foreign exchange earnings in 1982/83. The other, perhaps more crucial, problem is the increasing scarcity and cost of traditional household fuels, the massive impact of this scarcity on deforestation and the resultant insidious depletion of agricultural resources on which so much economic activity depends. Major programs of afforestation are urgently needed to correct the imbalance between supply and demand for woodfuels, and to enhance the agricultural ecology. However, this is a medium- to long-term solution and, in the short run, the development and utilization of indigenous fuel substitutes must be vigorously pursued.

1.2 In the industrial sector, there is also potential for substituting indigenous sources for wood and imported fuels. The Ethiopian Pulp and Paper Share Company uses imported pulp as its sole feedstock to produce different grades of paper. This entailed a foreign exchange cost of approximately $7 million in 1984 which will increase with a planned expansion of capacity unless local sources of pulp can be used. ECAFCO, the Ethiopian particleboard company, currently uses 6,000 tonnes of scarce eucalyptus wood annually, which further exacerbates the deforestation problem. Additionally, demand for a minimum of 21,000 tonnes of a densified fuelwood substitute to feed industrial boilers has been identified (see Annex 11).

1.3 Bagasse, a by-product of sugar cane processing, has the potential to significantly substitute for wood and imported materials in the domestic and industrial sectors. In densified form, bagasse could replace fuelwood in household or industrial use. Depithed bagasse could be used as a pulp feedstock in the local paper industry and as a substitute for wood feedstock in the manufacture of particleboard. In raw form, bagasse also could be burned by sugar mills to generate surplus electricity for sale to the national grid.

Surplus Bagasse Potential and the Sugar Industry

1.4 Ethiopia has a well-established cane sugar industry, which is owned and operated by the Ethiopian Sugar Corporation (ESC). There are three operating sugar factories -- Metahara, Wonji, and Shoa, which together process about 1,640,000 metric tons of cane and 186,000 metric tons of sugar per year (October to June). Operational characteristics of each factory are described in Annex 1. The amount of bagasse produced is approximately 470,000 metric tons at an average moisture content of 50%.

1.5 Except for the amount used for the filtration and start-up processes, most of the bagasse is burned "wet" (about 50% m.c.) as it emerges from the mills, with a small amount going to storage to take care of the fuel supply during occasional short mill stoppages. Industry-wide, there is only a small excess amounting to approximately 17,000 tonnes/year, of which 10,000 tons are used annually by the ESC lime kiln. The present net surplus of approximately 7,000 tons of wet bagasse, after supplying the lime kiln, is equivalent to 3,690 tonnes/year of bone dry bagasse.

1.6 A considerable expansion of the sugar industry is now in the planning stage. The Shoa factory will be expanded by 1989/90 and a new factory is to be constructed to process cane from the future Finchaa project. Exclusive of the latter, annual cane production after the expansion of Shoa will increase to 2,210,000 metric tons, and the accompanying increase in wet mill bagasse will be from 470,000 to 630,000 metric tons. Assuming that the present plant design is used for the expansion of the factory and that it then continues to operate as it does currently, the surplus of wet bagasse would be approximately 35,000 tonnes/year after discounting approximately 13,500 tonnes/year for the expanded lime kiln. The net surplus in terms of bone dry bagasse would amount to 12,549 tonnes/year.

1.7 The sugar factories were designed and constructed before the world oil crisis of 1973. The objective of the sugar factories was to burn as much bagasse as possible in the steam generation process as a means of incinerating what was commonly viewed as a waste product. Therefore, no serious attempts were made to use steam and bagasse efficiently. Since then, however, great strides have been made in the area of energy conservation, with the result that, per tonne of cane processed, a modern sugar factory can now produce surplus bagasse with a generation capability of up to 70 kWh, compared to some 15 to 18 kWh in a traditional factory. As for the steam utilization aspect of energy conservation, the ratio of weight of steam to weight of cane has improved from about 550-650 kg/tonne of cane processed to as low as 385 kg/tonne of cane processed.

1.8 On the steam generation side, the key technique for conservation is the drying of bagasse using boiler flue gases. This technique not only allows for a considerable recovery of waste heat (20-30%) but also improves the quality of the bagasse fuel, generally causing an increase in boiler efficiency. In addition, a larger percentage of the unburnt particles carried with the flue gases are trapped in the dried bagasse and recovered as additional fuel through the scrubbing effect of the drying system.

1.9 It is therefore evident that, in addition to the planned expansion of the industry, implementation of energy-conserving improvements in the sugar factories will enable the production of a much larger surplus of bagasse which could then be utilized in the domestic and industrial sectors of the economy.

Bagasse Energy Survey

1.10 Under the Joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP), a mission visited Ethiopia in January, 1985 to conduct a bagasse energy survey. The survey is part of a multi-country bagasse energy study 2/ to assess opportunities for increasing energy efficiency in existing and planned sugar mills which will enable them to produce surplus bagasse. This was an area identified as having a high priority for technical assistance in the recent Ethiopia Energy Assessment. The survey entailed an analysis of the technical, economic, financial and institutional feasibility of producing surplus bagasse in Ethiopia's sugar milling industry and the alternatives for using it. According to the mission's terms of reference, present and potential bagasse output was to be evaluated by:

(a) identifying the energy requirements of sugar factories and their related operations;

(b) assessing the impact of cane quality, machine performance and operating efficiency on bagasse production;

(c) evaluating the methods for improving efficiency of heat and power production from bagasse; and

(d) reviewing and evaluating technologies and systems for storing, processing and transporting surplus bagasse.

1.11 To assess surplus bagasse utilization, the actual and potential uses for the surplus were to be determined by considering:

(a) the use of bagasse fiber in the paper and pulp industry, including present and future demand for fiber, the suitability of bagasse fiber for paper production and the level of substitution for wood that is possible;

(b) the opportunity for energy self-sufficiency in the planned Finchaa sugar mill by modifying equipment procurement; and

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2/ A similar study has been completed for Guyana by the New and Renewables Division of the Energy Department, and ESMAP is completing a bagasse handling study for Mauritius.

(c) the impact of replacing bagasse currently used to meet mill energy needs with (i) an alternative imported fuel, (ii) electric power from the grid, or (iii) cane tops and trash.

1.12 Using data obtained from the above analyses, the mission was asked to prepare a preliminary outline of a project to generate and utilize surplus bagasse. The components of the report were to include (a) costing, (b) broad technical specifications, (c) sources of major equipment, (d) financial and economic rates of return, (e) the scope, outputs, timetable, and cost estimate of additional preparatory work to bring the recommended project to the engineering stage, (f) managerial issues, and (g) implementation options and constraints.

II. METHODS FOR INCREASING SURPLUS BAGASSE

2.1 This chapter uses simulated mill parameters to determine each sugar factory's material, thermal and electrical energy balances, as well as the current availability of surplus bagasse at each factory (a complete description of each mill's operations is presented in Annex 1). This information is used to determine how specific efficiency improvements in steam and electricity generation/utilization in the mills could be made. Then, the possibility of burning cane leaves and tops to increase the bagasse surplus is discussed. Finally, the resulting effects of such improvements on the surplus bagasse supply are summarized and quantified. The technical details of energy improvements for increasing surplus bagasse production are presented in Annex 2.

Simulated Mill Parameters

2.2 The utilization of bagasse energy in a sugar factory is determined by its material, thermal and electrical energy balances. For these balances to be accurate, ideally they should be generated from the acquisition of representative on-line data. Data are affected by, for example, the grinding rate, utilization of plant capacity, and frequency and duration of stoppages, as well as the method of processing cane into raw sugar, mill white sugar, refined sugar, alcohol, electrical energy, and other by-products.

2.3 These characteristics significantly affect the productive use of the energy available in bagasse and the amount of excess bagasse generated above the amount normally needed for the factory's internal energy requirement. For example, an idle boiler, during a temporary breakdown of the cane milling equipment, still burns bagasse as it is not feasible to completely shut down the boiler during such an occurrence.

2.4 Due to the limited time frame and the unavailability of equipment for continuous on-line data acquisition, the field mission made use of data provided by the staff of the Ethiopian Sugar Corporation, data from records, factory instruments readouts and observations made by mission members during factory visits, to simulate material and energy balances for the purpose of establishing the present level of bagasse energy utilization in the three Ethiopian factories. The simulation results are shown in Table 2.1.

2.5 In view of modifications made at the factories during the years prior to the 1983/84 crop, the staff of ESC indicated that the recorded data of 1983/84 would best represent the prevailing situation. The mission accepted the ESC staff's suggestion and made use of previous years' data only for background information purposes. The major critical outputs of the simulations, as well as measured parameters, were discussed with the staff of the ESC, who confirmed the figures. The mission therefore believes that the simulations are a fairly accurate representation of the present state of material and energy balances of the factories.

Table 2.1: SIMULATED MAJOR PARAMETERS PER CANE GRINDING HOUR

	Unit	Metahara	Wonji	Shoa
Steam				
Process use	kg/tch a/	481.75	580.00	433.00
Other use	kg/tch	18.63	48.00	48.00
Total	kg/tch	500.38	628.00	481.00
Electrical Energy				
Generation	KWh/tc b/	18.77	17.85	18.12
Internal Use	KWh/tc	18.77	17.85	18.12
Import	KWh/tc	-	-	-
Export	KWh/tc	-	-	-
Mill Bagasse				
Moisture	%	50.19	47.74	49.91
HHV (heating value)	MJ/kg	9.54	10.00	9.59
in Cane	%	29.01	28.63	28.23
Production	kg/hr	60,118	17,697	19,482
Other Factory usage	kg/hr	1,804	531	585
Available as Fuel	kg/hr	58,314	17,166	18,897
To boiler as fuel	kg/hr	54,364	16,168	16,253
Gross Excess	kg/hr	3,950	998	2,644
Utilization Of Gross Excess To				
Fuel Storage (for deferred use)	kg/hr	2,228	223	118
For Ext/-Factory use				
(e.g. lime kiln)	kg/hr	0	0	1,938
Excess	kg/hr	1,722	775	588
Supplemental Fuel				
(in equivalence Bag)	kg/hr	1,722	0	0
Net Excess	kg/hr	0	775	588

a/ t.c.h. = metric tons of cane per hour.
b/ t.c. = metric tons of cane.

Bagasse Production and Utilization Under Existing Conditions

Metahara

2.6 During the 1983/84 crop season, Metahara processed 951,359 tonnes of cane in 4,574 hours of grinding at an hourly rate of 208 tonnes. With an 80% mechanical time efficiency, the daily grinding rate was 19.2 hours. Of the mill bagasse hourly flow, 2,228 kg/hr were retained for storage in order to have sufficient reserve for 'deferred usage' (see Fig. 1). The latter occurs when the factory is not grinding cane due to mechanical and/or processing problems. On average, 4.8 hours of such occurrences were experienced daily and during that period, the steam flow was maintained at 18,750 kg/hr, with 8,912 kg of bagasse reclaimed from storage, to generate approximately 2,500 kW and to ensure minimal exhaust steam flow to the process. This steam flow is approximately 15% of the boiler maximum capacity rating, which is considered a safe turn-down level for the boiler.

2.7 In addition to the amount of bagasse retained for deferred usage, the mill bagasse flow was discounted by 3% in Table 2.1 for 'other factory usages', i.e., 1,804 kg/hr for process use, start-up, shutdown, and losses. The process use was principally for the rotary vacuum filters. The feed to these filters (mud from the juice clarifier) needs to be conditioned with fine bagasse (approx. 8 kg/ton cane) to improve its filtration characteristics.

2.8 From Table 2.1, it is apparent that, after the mill bagasse has satisfied (a) the boiler fuel requirement during cane grinding hours, (b) the amount for deferred usage, and (c) the amount for other factory usage, an apparent excess of 1,722 kg/hr is still available. In reality, this excess is a fictitious surplus since Metahara had to burn an equivalent amount of fuel oil due to inadequate bagasse handling facilities. This supplemental fuel was burnt at an average rate of 2.96 tons/8 hour shift, at a cost of Br. 500/tonne. From dry to wet weather conditions, this consumption varied between 2 and 10 tonnes/shift. The high consumption of fuel oil, in the presence of excess bagasse, is mostly attributable to the inadequate design of the bagasse storage reclaiming system. If the system were improved, then all the apparent surplus of bagasse would be burned instead of fuel oil, leaving no excess. The mission is confident that, with a modified bagasse reclaim system, Metahara should be self-sufficient in fuel.

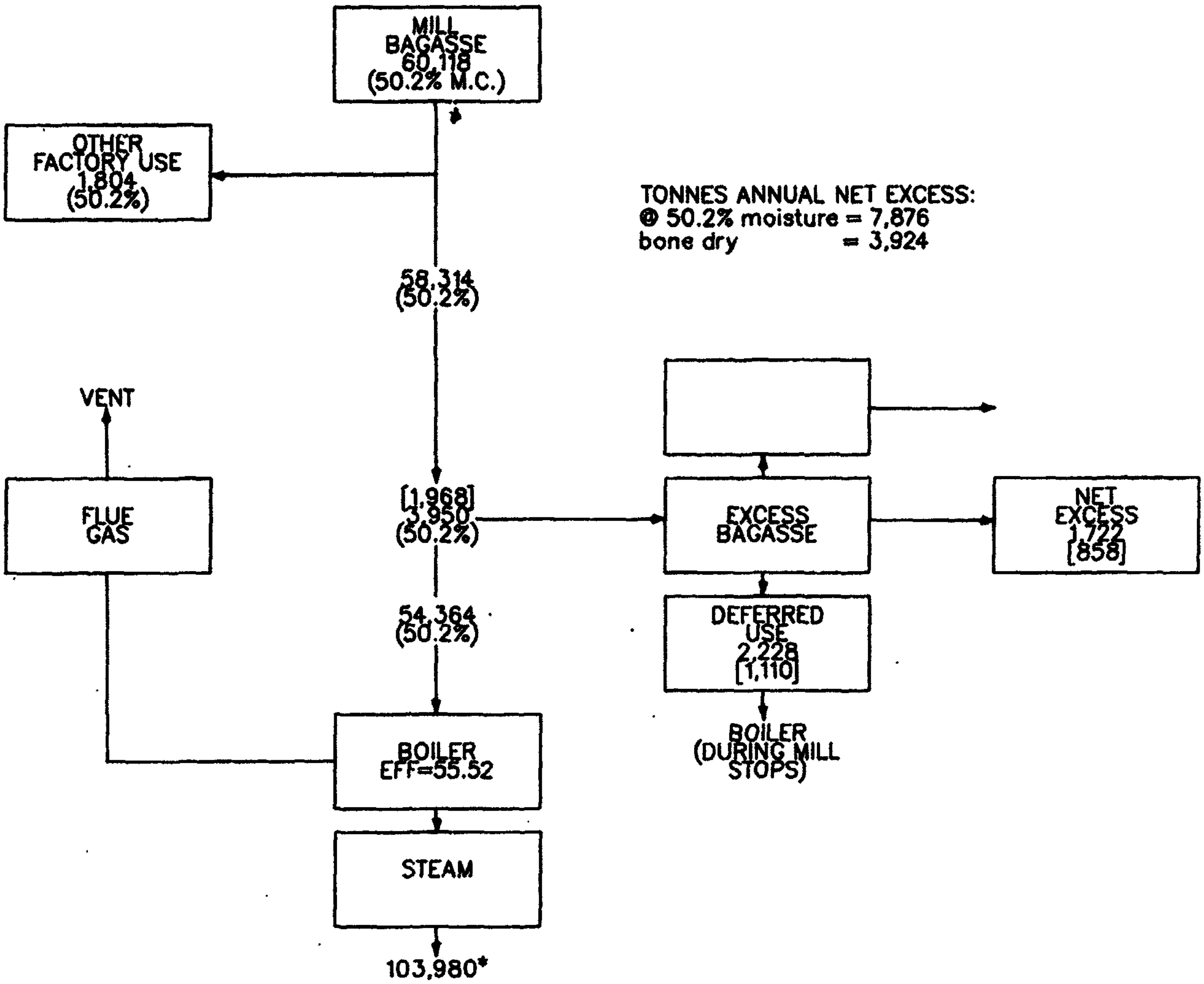
Wonji

2.9 During the 1983/84 crop season, Wonji processed 331,029 tonnes of cane in 5,357 hours of grinding at an hourly rate of 61.79 tonnes. With a 92.62% mechanical time efficiency, the daily grinding rate was 22.23 hours. Of the mill bagasse hourly flow, 223 kg/hr were retained for storage in order to have sufficient reserves for deferred usage (see Fig. 2). On average, 1.77 hours of stoppages were experienced daily; and during that period, the steam flow (approximately 15% of boiler M.C.R.) was maintained at 5,873 kg/hr, with 2,800 kg of bagasse reclaimed from storage, to generate approximately 400 kW and to ensure minimal exhaust steam flow to the process.

2.10 As in the case of Metahara, the mill bagasse flow was discounted by 3% for other factory usage, i.e., 531 kg/hr, although this plant has no rotary vacuum filter but instead uses 14 filter presses. The latter's feed is conditioned with fine bagasse prior to filtration. From Table 2.1, it is evident that Wonji is self-sufficient in fuel and further produces a bagasse surplus of 775 kg/hr for 'external usage'.

Figure 2.1

METAHARA
WET MILL BAGASSE FLOW



Note : Open figure is bagasse flow, wet basis, in kgs/hour
Figure in [ ] is bagasse flow, bone dry, in kgs/hour
Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

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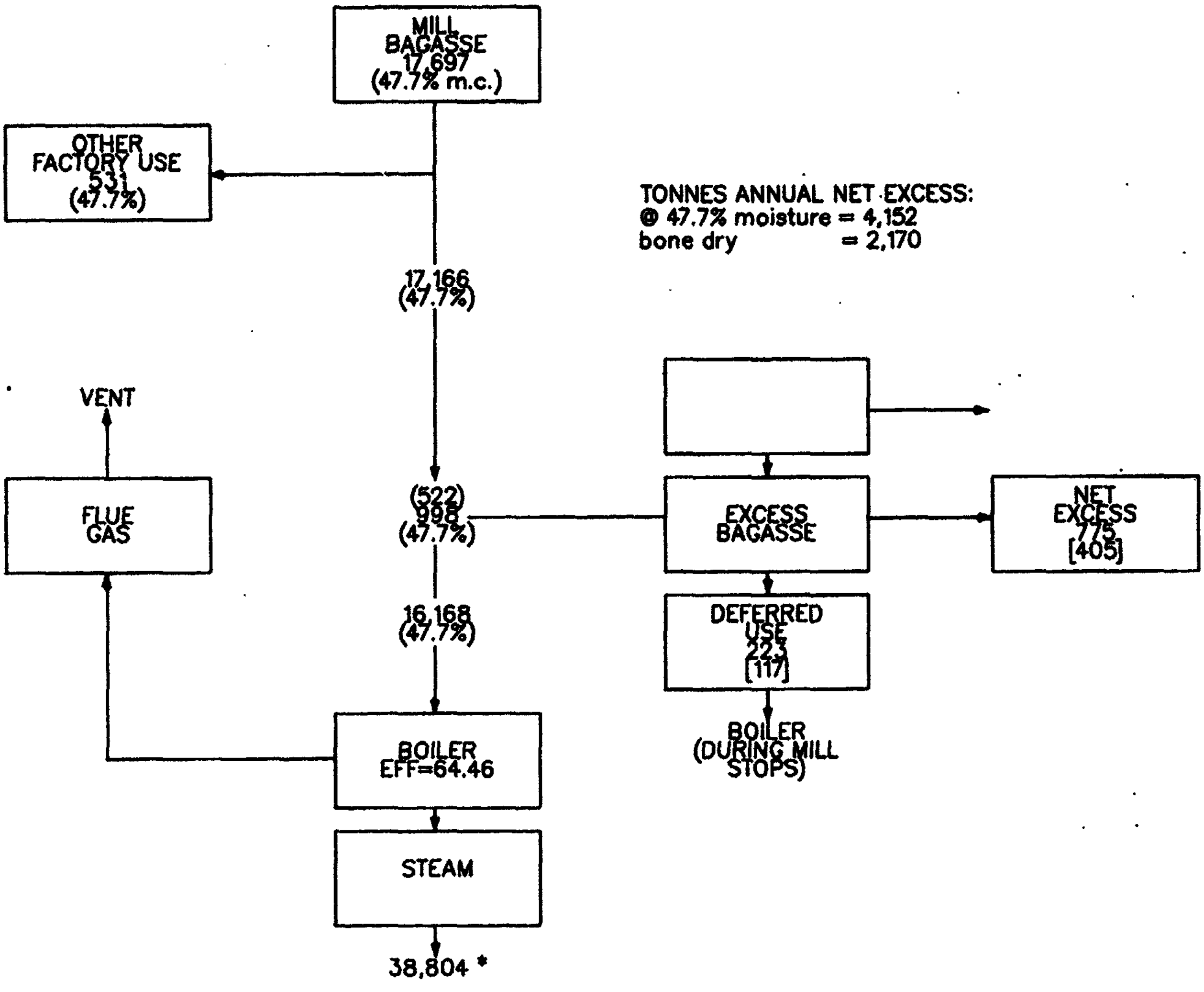
Figure 2.2

WONJI
WET MILL BAGASSE FLOW



Note : Open figure is bagasse flow, wet basis, in kgs/hour
: Figure in [ ] is bagasse flow, bone dry, in kgs/hour
: Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

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Shoa

2.11 During the 1983/84 crop season, Shoa processed 356,176 tonnes of cane in 5,161 hours of grinding at an hourly rate of 69.01 tonnes. With a 95% mechanical time efficiency, the daily grinding rate was 22.8 hours. Of the mill bagasse hourly flow, 118 kg/hr were retained for storage in order to have sufficient reserve for 'deferred usage' (see Fig. 3). On an average, 1.2 hours of stoppages were experienced daily and during that period the steam flow, approximately 15% of boiler M.C.R., was maintained at 5,608 kg/hr. 2,242 kg of bagasse was reclaimed from storage to generate approximately 400 kW and to ensure minimal exhaust steam flow to the process.

2.12 As in the case of Wonji, the mill bagasse flow was still discounted by 3% for 'other factory usage,' i.e., 585 kg/hr, although this plant uses 6 filter presses in addition to 2 Rotary vacuum filters, the latter being the only filters that require fine bagasse for feed conditioning.

2.13 From Table 2.1, it is evident that Shoa is self-sufficient in fuel and further produces a bagasse surplus of 2,526 kg/hr, which represents an annual surplus of 13,037 tonnes, about 10,000 tonnes of which are used by a lime kiln. This lime kiln has a capacity of 3,300 tonnes of quick lime and supplies the three factories. In bone dry terms, this currently leaves a net excess of 1,520 tonnes of bagasse and would mean 10,379 tonnes from an expanded Shoa.

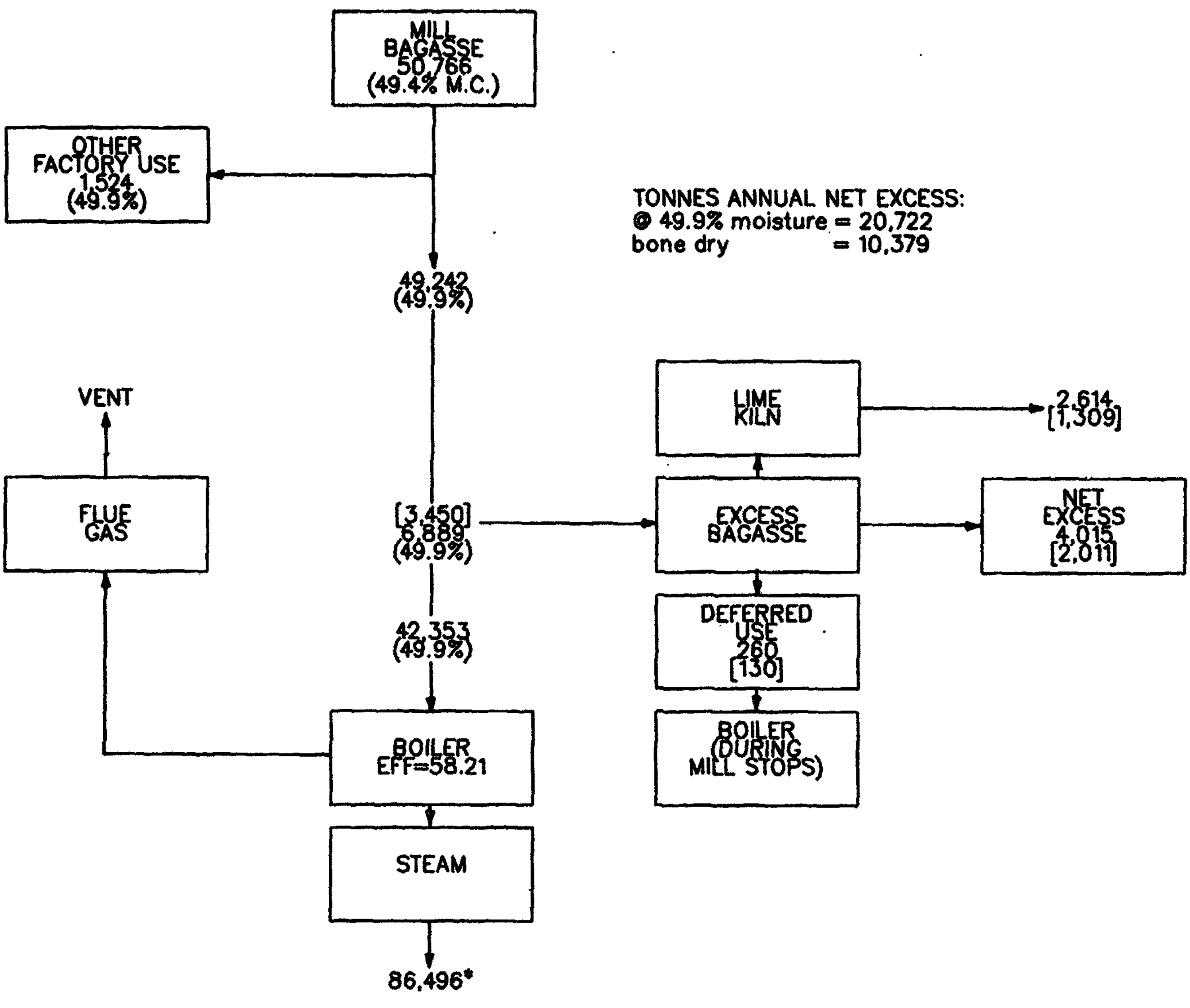
Expanded Shoa

2.14 By 1990, this plantation will grow 4,600 hectares of cane, and the daily grinding rate will be augmented to 4,100 tonnes per day. Assuming that the crop is processed in the same length of time that presently prevails, the amount of cane processed would then be 928,114 tonnes, i.e., 179 tonnes of cane per hour with 50,766 kg of bagasse per hour. Assuming that the expanded factory operates under the same present conditions, the gross excess would be 6,889 kg/hr or 35,556 tonnes annually.

2.15 With the expanded factory, the sugar industry's lime requirement will increase by 34.9% with a corresponding increase in fuel for the lime kiln i.e., from 10,000 to 13,490 tonnes per year or 2,614 kg/hr. Therefore, the net surplus would be 4,015 kg/hr after discounting 260 kg/hr for deferred fuel use.

Figure 2.3

EXPANDED SHOA
WET MILL BAGASSE FLOW



Note : Open figure is bagasse flow, wet basis, in kgs/hour
: Figure in [ ] is bagasse flow, bone dry, in kgs/hour
: Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

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Summary: Current Bagasse Surplus

2.16 The present annual production of surplus bagasse in the ESC factories is shown in Table 2.2. 'Excess Bagasse' is defined as the difference between weight of bagasse from mill bagasse less 'other factory usage' and less the weight of bagasse feed to boilers during grinding hours. 'Net Excess Bagasse' is defined as the excess remaining after deducting from 'Excess Bagasse' the amount of bagasse burned from storage when the mills are down, herein termed 'Deferred Use', and deducting the amount for 'external factory use', such as the lime kiln.

Table 2.2: PRESENT ANNUAL EXCESS BAGASSE SUPPLY
(In Tonnes, Bone Dry Basis)

Location	Excess bagasse	Net excess bagasse
Metahara	9,002	0 a/
Wonji	2,796	2,170
Shoa	6,835 b/	1,520
Shoa (expanded)	17,806 b/	10,379

a/ In actuality, at Metahara there is a surplus of 3,924 tonnes (bone dry equivalent) of bagasse which cannot be burned due to the existing reclaiming system. Thus the factory, on average, has to burn 2.96 tonnes/8 hour shift of fuel oil, because of this ineffectual reclaiming system. Assuming that the reclaiming system is made effective, then this surplus of bagasse would be burned and the oil burning would be eliminated, leaving no bagasse surplus.

b/ Shoa presently supplies 5,010 tonnes (bone dry equivalent) of bagasse to the lime kiln and will supply 6,756 tonnes after the expansion.

Finchaa

2.17 To meet the projected growth in domestic sugar demand, a new sugar estate, with an ultimate production capacity of 125,000 tonnes of sugar per year, is planned to be built at Finchaa, about 345 km northwest of Addis Ababa. The initial grinding capacity of the factory will be 4,000 tonnes of cane per day (TCD), expandable to 6,000 TCD. During the initial phase the factory will process 708,000 tonnes of cane per year from 6,114 hectares to achieve a production of approximately 84,000 tonnes of sugar. The mission consultants reviewed the plans for the factory, with a view to providing energy-conserving suggestions which would increase surplus bagasse production beyond that possible in the original plan. The review and flow diagrams are presented in Annex 3. The factory and its potential contribution of excess bagasse to the industry-wide supply was not considered in structuring the proposed project activity in Chapter 4 since the implementation schedule of the Finchaa project is still undefined at this stage.

Increasing Surplus Bagasse By Energy Improvements

2.18 Surplus bagasse production can be enhanced in two principal ways: (a) by modifying factories, and (b) by using cane leaves and tops as fuel. The latter will be discussed in sections 2.25-2.27. The former can be achieved in ESC mills because of their favorable operating conditions. Specifically, surpluses can be generated via mill modifications by:

(a) drying bagasse before using it in mill boilers;

(b) making steam and electricity utilization improvements; and

(c) using unburnt particles captured in the dryer for burning in mill boilers.

The technical issues involved in achieving these modifications are presented in Annex 2.

2.19 For several reasons, the ESC mills are good candidates for increasing surplus bagasse. The continuous operation of the factories, except for a scheduled 8-hour stop per month for maintenance (72 hour/crop), creates an environment conducive to optimal bagasse utilization. Further, exclusive of Metahara, the high mechanical operating time efficiency of the factories (in excess of 90%) further contributes to optimal bagasse utilization; Metahara, which has recently been expanded, is still in the process of commissioning and is expected to reach a 90% plus level in the near future. The other major asset of the ESC factories in achieving optimal bagasse utilization is the reliability and adequacy of the cane supply from the fields. In view of the foregoing, the mission is confident that a number of improvements can be implemented that will lead to the generation of greater bagasse surpluses.

Drying Bagasse

2.20 Steam generation efficiency can be significantly improved by drying bagasse before burning it. The use of a bagasse dryer as an additional means of recovering waste heat offers many advantages: (a) permitting a considerably higher heat recovery; (b) reducing the volume of flue gases; (c) lowering their dew point; and (d) capturing most of the entrained particles through a scrubbing effect. The effect of drying, using flue gases, on the efficiency of steam generation and on excess bagasse production is documented in Table 2.3.

Steam and Electrical Improvements

2.21 Improving steam and electrical utilization at the mills to yield surplus bagasse involves reducing process steam requirements, connecting factory electrical buses to the grid and improving electrical power factors. By making changes in the boiler houses, process steam use can be reduced. By synchronizing factory generators with the grid, the demand for a high level of process steam, and hence bagasse, could be reduced. By installing capacitors to generate reactive power, the power factor of the factory systems could be improved and less bagasse-based electricity would have to be generated.

Table 2.3: IMPROVED EFFICIENCY OF STEAM GENERATION THROUGH BAGASSE DRYING

	Metahara	Wonji	Shoa	Expanded Shoa a/
Boiler Efficiency (%)	62.7	68.7	63.1	63.1
Expected Excess Bagasse:				
Moisture (%)	31.0	29.8	38.0	38.0
H.H.V. (MJ/kg)	13.14	13.36	11.83	11.83
Tonnes Telquel b/	32,682	7,634	15,975	41,627
Tonnes Bone Dry	22,551	5,359	9,904	25,808

a/ Extrapolation.
b/ 'Telquel' refers to the actual moisture content of the bagasse, in this case between 29.8% and 38.0%.

2.22 Steam and electricity utilization improvements will add the following quantities of additional excess bagasse (bone dry basis) at each factory:

Metahara	9,269 tonnes
Wonji	14,801 tonnes
Shoa	5,687 tonnes
Shoa (expanded)	14,816 tonnes

In Table 2.4, these figures are added to the gains from bagasse drying to yield the following results.

Table 2.4: COMBINED EFFECTS OF BOILING HOUSE IMPROVEMENTS & BAGASSE DRYING

	Metahara	Wonji	Shoa	Expanded Shoa a/
Boiler Efficiency (%)	62.0	66.1	62.3	62.3
Expected Excess Bagasse:				
Moisture (%)	33.4	38.2	40.2	40.2
H.H.V. (MJ/kg)	12.69	11.79	11.41	11.41
Tonnes Telquel	47,778	32,621	26,072	67,937
Tonnes Bone Dry	31,820	20,160	15,591	40,624

a/ Extrapolation.

Capturing Unburnt Bagasse

2.23 As mentioned in para. 2.20, a scrubbing effect takes place in a dryer which results in the capture of most unburnt particles entrained in the flow of flue gases. Based on data from Hawaiian and Mauritian sugar mills, it is estimated that 65% of these losses are recoverable for burning, thus freeing up more surplus bagasse for other uses. The estimated amounts, on a bone dry basis, are as follows:

Metahara	10,880 tonnes
Wonji	2,333 tonnes
Shoa	3,505 tonnes
Shoa (expanded)	9,133 tonnes

Capturing this amount of particles through drying would free up an equivalent amount of bagasse.

2.24 Summing each addition to excess bagasse contributed by a factory improvement, total bagasse availability is estimated as:

Metahara	42,700 tonnes
Wonji	22,493 tonnes
Shoa	19,096 tonnes
Shoa (expanded)	49,757 tonnes

After subtracting out deferred use by the factories and the lime kiln, net excess bagasse is as set out in Table 2.5.

Table 2.5: NET EXCESS BAGASSE FROM FACTORY MODIFICATIONS
(Tonnes, bone dry basis)

Source of Excess	Metahara	Wonji	Shoa	Expanded Shoa
Due to drying and steam utilization improvements	26,743	19,533	10,276	33,197
Due to capture of unburnt particles in dryer	10,880	2,333	3,505	9,133
Total	37,623	21,866	13,781	42,330

Utilization of Cane Leaves and Tops as Boiler Fuel

2.25 Cane leaves are produced in abundance during the life cycle of a cane plant. Green leaves contain approximately 50% dry matter and therefore constitute an important source of fibrous material similar in nature to the fiber found in bagasse. The management at Shoa has determined that 9 tons of cane tops, at 25% moisture, are available per hectare. The average yield of cane per hectare at Shoa, for the 1983/84 crop, was 148.33 tonnes. Therefore the ratio of 25% moisture cane tops to cane is found to be 0.0607. As no such determination was carried out at Metahara or Wonji, the mission has applied this ratio to these two plantations in determining the available amount of cane top, as presented in Table 2.6.

Table 2.6: CANE TOPS FROM CANE FIELDS
(In Tonnes)

	Metahara	Wonji	Shoa	Expanded Shoa a/
Cane per Crop	951,359	331,029	356,176	928,114
Cane Tops:				
@ 25% moisture	57,724	20,085	21,611	56,314
Bone Dry Basis	43,293	15,064	16,208	42,235

a/ Extrapolation.

2.26 In the mission's opinion, these figures seem low since it has been established by a competent study in the Dominican Republic that the leaves left in a cane field at harvest amount to 67% on a green basis, corresponding to 33.5% on a dry basis, of the net cane weight harvested. The mission recognizes, however, that conditions may be different in Ethiopia and recommends that a more in-depth study be initiated as this material may become an important contributor to Ethiopia's energy supply.

2.27 If all dried loose surplus bagasse were converted into densified form for economic storage and transportation, then a net excess of 85% (bone dry basis) displaced by the cane tops would be recovered; the other 15% would be used as fuel to dry this additional surplus bagasse since all available heat in the flue gases would be insufficient to dry it to the 12% moisture level necessary for densification. The surplus of densified bagasse created by the use of cane tops as fuel is as shown in Table 2.7.

Table 2.7: NET SURPLUS BAGASSE RESULTING FROM USE OF CANE TOPS
(In Tonnes)

Content	Metahara	Wonji	Shoa	Expanded Shoa a/
@ 12% moisture	41,817	14,550	40,795	15,655
Bone Dry	36,799	12,804	35,900	13,777

a/ Extrapolation.

Summary of Net Excess Bagasse

2.28 Table 2.8 summarizes the potential annual excess bagasse production in each factory due to factory modifications and the use of cane leaves and tops.

Table 2.8: SUMMARY OF ANNUAL EXCESS BAGASSE
(Tonnes, bone dry basis)

	Metahara	Wonji	Shoa	Expanded Shoa a/
A. Factory Modifications				
Due to steam utilization improvements	9,269	14,801	5,687	14,816
Due to drying of bagasse	22,551	5,359	9,904	25,808
Due to capture of unburnt particles in dryer	10,880	2,333	3,505	9,133
Sub-total	42,700	22,493	19,096	49,757
Less 'Deferred Use'	5,077	627	305	671
Less 'External Use' (e.g. lime kiln, etc.)	-	-	5,010	6,756
Sub-total Net Excess	37,623	21,866	13,781	42,330
B. Use of Cane Leaves & Tops	43,293	15,064	16,208	42,235
Less 15 % needed for drying	6,494	2,260	2,431	6,335
Sub-total Net Excess	36,799	12,804	13,777	35,900
C. Total Net Excess Bagasse	74,422	34,670	27,558	78,230

a/ Extrapolation.

III. ECONOMIC OPPORTUNITIES FOR UTILIZING SURPLUS BAGASSE

3.1 In sugar-producing countries faced with power shortages and high imported fuel costs, the most logical option for utilizing surplus bagasse is generally additional electricity generation at the mills for export to the grid. This enables augmentation of public electricity supplies with much lower total capital investments than would be needed to add generating capacity with conventional utility plants. Ethiopia, with its considerable hydropower resources, is in a different situation and currently would benefit little from incremental addition of power from surplus bagasse. Other bagasse utilization options exist which have a higher economic priority than electricity generation. The most important of these is using densified bagasse as a fuel substitute in the domestic and industrial sectors. Other potential uses include substituting processed bagasse for pulp and wood in the paper and particleboard industries. The possibility of using bagasse as filler for cattle feed has also been suggested but will not be possible, since all the molasses produced will be used for ethanol and baker's yeast production at the proposed Shoa facility in 1989/90.

Fuel Substitute for Households and Industry

3.2 The Ethiopia Energy Assessment highlighted the extremely critical forest depletion rates in the country, a large part of which is due to extensive overcutting to obtain firewood for household purposes. As the forests have receded, the cost of woodfuel has risen dramatically, from $9 to $90 per tonne between 1973 and 1983. As a consequence, urban household expenditure for fuelwood now accounts for some 20% of family income. The scarcity of fuelwood has also resulted in the increasing diversion of dung from fertilizer use to fuel use, thereby reducing agricultural productivity in some areas. If bagasse was an acceptable fuelwood substitute for households its economic value would be considerable.

3.3 Another possibility is to use bagasse as an industrial fuel in industries which now burn wood (e.g., tobacco barns), co-fire fuel oil with other waste materials (e.g., brick kilns), or have electric boilers (e.g., oil mills). These industries could use 21,000 tonnes of densified fuel immediately, with an economically feasible potential demand of 95,000 tonnes per year (see Annex 11).

Need for Densification

3.4 For use as solid fuel, the surplus bagasse obtainable from the three existing factories must be stored on-site, transported to the marketplace and in turn stored prior to sales and utilization. Therefore, the dried loose excess bagasse must be converted into a densified form to improve the economics of its storage, transportation and handling, and to permit its use as a boiler fuel. Densification increases the bulk density of dried bagasse from 30-60 kg/cubic meter to 640-720 kg/cubic meter. In addition, densification improves the keeping quality of the bagasse, a prerequisite for safe storage, by converting the fermentable sugars contained in the loose bagasse into a non-fermentable form, thereby eliminating risks of spontaneous combustion and storage losses, which are usually caused by the exothermic fermentation process occurring in the stored pile.

3.5 Bagasse densification is possible by three main methods: baling, briquetting and pelletizing. Bales have the advantage that they can be made with moist bagasse and can then be sun-dried if stacked outdoors in piles with sufficient gaps to allow air circulation. The first disadvantage of bales is the costly requirement of wires to hold the bagasse together. Another drawback is the size of the bales which does not allow for cheap bulk handling methods. The most critical disadvantages are:

(a) the loss of dry matter during storage; researchers have reported losses in excess of 15-24% after 3 months of storage 3/ even though moisture stabilization (25%) is reached after 2.5 months; and

(b) the risk of spontaneous combustion.

3.6 Binderless densification into pellets or briquettes is possible when the bagasse is dried to a moisture content (m.c. wet-basis) of 12 to 14%. Artificial drying methods must be applied since the m.c. must be kept within a tolerance of ±1.5%. Bagasse pellets are produced with diameters between 6 to 25 mm. Briquette diameters range from 40 to 125 mm. The types and costs of densifiers used in the densification process are discussed in more detail in Annex 4. Pellets and briquettes have been successfully combusted in industrial equipment but the former have not yet been demonstrated as suitable for burning in simple household stoves. Briquettes of various residues have been used as a household fuel in several countries, e.g. The Gambia, India and Thailand; because of their larger diameter they are probably less difficult to burn in cooking stoves than pellets. Laboratory trials indicate that agricultural residue briquettes used in cookstoves exhibit similar or superior burning characteristics to Ethiopian eucalyptus.

Potential Solid Fuel Production

3.7 The amount of surplus bagasse that could be made available in densified form is presented in Table 3.1. It should be noted that the amounts shown in Table 3.1 are somewhat lower than the amounts shown for the loose dried form in Table 2.8. The reason is that, the lower the

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3/ Mauritius Sugar Industry Research Institute, 30th Annual Report, 1983.

target moisture content of the surplus bagasse, the higher will be the moisture of the bagasse going to the boiler, thereby lowering the boiler efficiency and resulting in more bagasse being burned (see Annex 2). However, the amount of usable energy obtained from the densified bagasse is greater than that available from the loose dried bagasse, which partially offsets this effect.

Table 3.1: TOTAL POTENTIAL DENSIFIED EXCESS BAGASSE PRODUCTION

		Metahara	Wonji	Shoa	Expanded Shoa
Tonnes (Bone Dry)		35,770	20,430	12,445	38,975
Tonnes (Telquel)		39,338	22,903	13,806	43,236
Moisture	%	9.07	10.80	9.86	9.86
H.H.V	(MJ/kg)	17.27	16.93	17.12	17.12

The annual potential net output of densified bagasse, on a bone dry basis, is expected to be 95,175 tonnes, of which 35,770 tonnes, 20,430 tonnes and 38,975 tonnes will be produced respectively at Metahara, Wonji and the expanded Shoa. This is equivalent to approximately 180,000 tonnes of wood (air dried) or 60,300 toe.

Bagasse As Pulp Feedstock

3.8 The Ethiopian Pulp and Paper Share Company (EPPSC) operates the country's main paper plant. The Government and the IFC own respectively 70% and 30% of its shares. The EPPSC facility is located in the province of Shoa, 1.5 km and 7 km respectively from the Wonji and Shoa cane sugar factories. The purpose of locating the facility near these cane sugar factories was to use their moist depithed bagasse as feedstock for an eventual wet depither and pulp manufacturing plant at the EPPSC facility's present location. A feasibility study pertaining to this subject was conducted in 1981 by Jaakko Poyry (Finland) for a pulping plant of 30,000 tonnes/year. The project was abandoned because of its excessively high investment cost. A smaller facility is currently being assessed by Sandwell Ltd. (Canada).

3.9 Presently, EPPSC uses imported pulp as feedstock to produce different grades of paper such as printing, writing, wrapping, corrugated, and board for book covers. The facility consists of one paper machine which has a nominal capacity of 7,500 tonnes/year but on occasions has attained 9,000 tonnes/year. Attached to the paper machine are two converting plants: one produces 3,000 tonnes/year of corrugated boxes, and the other is a converting/finishing plant which produces approximately 10,000 tonnes/year of sheet and stationery paper. The other paper-related activities in Ethiopia are:

(a) a conversion plant, in Addis Ababa, operated by the Ethiopia Printing Corp., and

(b) an old paper plant, located in Asmara, which uses waste paper as feedstock.

3.10 The EPPSC facility presently satisfies 35% of the domestic demand. EPPSC employs 574 workers, and has annual sales of Br. 31 million. Its production cost is Br. 23.2 million, of which Br. 15 million is for imported material, namely pulp and chemicals. Of the imported materials cost, Br. 14 million is for pulp purchases, mainly from Sweden and the U.S. During the past three years, most imports have been from the U.S.

3.11 The total import of pulp for fiscal year 1984/85 is shown in Table 3.2.

Table 3.2: MIX OF IMPORTED PULP

Type of Pulp	Quantity Imported (tonnes/year)
Semi-Bleached Softwood	1,900
Unbleached Softwood	1,146
Bleached Softwood	1,694
Bleached Hardwood	3,736
Bleached Mechanical	1,194
TOTAL	9,670

The average cost of the pulp mix delivered to the plant site for fiscal year 1984/85 was US$710/tonne, i.e., $600/tonne c.i.f. Assab and $110 for inland transportation.

3.12 Bagasse is chemically similar to hardwood, but has a higher pentosan and total ash content. According to EPPSC, the components of the mix that eventually could be substituted by depithed bagasse are the short fiber bleached 'hardwood' and the 'mechanical' pulp, i.e., a total of 4,930 tonnes/year. The price of the bleached hardwood pulp, from regular suppliers, is currently $500/tonne c.i.f. Assab, and that of 'mechanical' pulp is currently $423/tonne c.i.f. Assab. While regular supplies are basically constant in price, the spot market price for bleached hardwood reached a high of $742 c.i.f. Assab in mid-1980 while the low registered during the past three years was $378.

3.13 A feasibility study has been carried out for modernizing the existing facility and for increasing its production capability by 50%. The final engineering has been completed by Arrow Project Contracts Ltd., and issuing of the tenders was expected to occur in March 1985. This modernization and expansion phase is expected to be completed one year after issuing the tender and will be financed from EPPSC's own funds. A second expansion phase is expected to be completed in 1988/89. The addition of a second paper machine for fine paper production will bring the capacity of the facility to 25,000-30,000 tonnes/year. The existing paper machine will then be converted to produce commercial grade paper.

3.14 EPPSC has also requested a feasibility study, fielded in July 1985 by Sandwell of Canada, for a 15,000-20,000 bleached bagasse pulp plant. The plant will only be feasible, on grounds of economies of scale, if the second phase expansion is completed. EPPSC is now considering the addition of the pulping plant after the second phase expansion, i.e., the pulping plant should be fully operational in 1995, assuming 3 years to complete construction. The investment cost of this plant is expected to be at least $25 million.

3.15 The amount of surplus bagasse that could be generated at Wonji and expanded Shoa, the two neighboring sugar factories, is 23,125 and 45,236 tonnes (bone dry equivalent) respectively, making a total of 68,361 tonnes for both factories. At a ratio of 1.925 bone dry tonnes of depithed bagasse/tonne of pulp, the amount of pulp that could be made from this surplus is 29,553 tonnes, which is in excess of the projected capacity of the proposed pulp plant (15,000-20,000 tonnes/year). Hence, it would be possible for these two sugar factories to produce enough surplus bagasse to satisfy the needs of the pulp plant while still leaving a surplus of 29,861 to 39,486 bone dry tonnes, i.e. 44-58% of the original surplus, for densification as a fuelwood substitute.

3.16 If the requirement of the pulp plant was limited to the availability of depithed bagasse at Wonji, the nearest sugar factory, only one moist depithing operation would be needed and transportation of bagasse in loose form from Shoa to EPPSC would not be necessary. Baled bagasse, briquettes or pellets hauled from Shoa could then replace the bagasse needed by Wonji to raise steam. Table 3.3 shows the resulting bagasse balance at Wonji. By receiving 12,633 tonnes (bone dry) from Shoa to satisfy the balance of its boiler requirement of 27,268 tonnes (bone dry), Wonji would be able to liberate all the depithed fraction of its bagasse, or 32,205 tonnes (bone dry). Wonji then could convert this depithed bagasse into 16,730 tonnes of pulp, which is within the designed capacity requirement of the proposed pulp plant.

Table 3.3: BOILER FUEL BALANCE AT WONJI

Type of Fuel	Quantity Produced
	tonnes, bone dry basis
Bagasse Produced @ Wonji	= 46,840
Depithed Bagasse for Pulping	= 32,205
Pulp Production	= 16,730
Pith Fraction to Boiler	= 14,635
Densified Bagasse From Shoa	= 12,633
Total To Boiler as Fuel	= 27,268

Bagasse for Particleboard

3.17 Bagasse is still used in a number of countries as the raw material for particleboard, e.g., in Cuba, El Salvador, Brazil, Egypt, Mauritius, and Pakistan; other countries such as Jamaica, Venezuela and South Africa have discontinued the manufacturing of particleboard from bagasse for economic and technical reasons. At present, ECAFCO, the particleboard factory in Addis Ababa, produces approximately 6,000 cubic meters of board per year using eucalyptus wood as raw material. Recently, successful tests have been carried out by using bagasse instead of eucalyptus wood. ECAFCO's technical staff concluded that glue consumption (glue is an imported product) can be reduced by 20% when replacing eucalyptus wood with bagasse. However, equipment wear would be unacceptable unless the bagasse was depithed for full-scale production.

3.18 Particleboard manufacture -- in contrast to the production of pulp -- is a dry process, i.e., the raw materials must be available as dry as possible. A board usually consists of several layers -- in most cases one core layer and two surface layers. Before the fibers are mixed with glue, the core layer is dried to a moisture content (m.c.) of 2 to 3% and the surface layers to 9 to 10% m.c. The bagasse needs to be depithed before it is transported to the board mill. Approximately 35% of fines are removed from the bagasse (most of it pith) by means of depithing machines. A moist depithing facility at Shoa, for example, would cost approximately $500,000.

3.19 The depithed bagasse should be baled in moist condition, and then the bales should be stacked adjacent to the sugar mill for 3 to 4 months. Sufficient air gaps between the bales must be provided to allow the escape of heat and alcohol vapors. Fresh bagasse with its high sugar content is not suitable for board production. In order to destroy most of the sugar in the bagasse, the bagasse must not be dried too rapidly. Natural drying in Ethiopian climatic conditions has the great advantage that most of the sugar contained in the bagasse is eliminated by gentle fermentation during the first 3 to 4 months of storage. In upper Egypt (Kom-Ombo), with climatic conditions similar to Ethiopia, this method has been successfully used in a board factory for approximately 20 years.

3.20 The moisture content of the baled bagasse stored in the open drops to 30% after the first month, to 22-25% after the second and to 10-15% after the fourth month. The bales should be transported when they have reached a low m.c. The weight of the moist bales should not exceed 50 kg to allow for manual stacking and to provide sufficient surface area for the escape of the vapors. After natural drying, a 50 kg (moist) bale will weigh approximately 31 kg, and have a density of approximately 320 kg per cubic meter. But it should be remembered that a significant amount of dry solid loss is experienced during storage.

3.21 Approximately 800-900 kg of bagasse at 15% m.c.w.b. are required to produce one cubic meter of particleboard. Therefore, the

ECAFCO capacity of 6,000 cubic meters of board per year could be met by supplying 5,000 tonnes of depithed 15% m.c.w.b. bagasse bales per year, or about 15,000 to 17,000 tonnes per year in terms of wet mill bagasse, after accounting for dry solid losses. The Wonji/Shoa complex, after factory modifications, could produce surplus bagasse sufficient to meet the total needs of the particleboard factory in addition to supplying the pulp plant. The specification of a 5 tonne per hour (TPH) depithing/baling plant for this purpose is briefly discussed in Annex 5.

Bagasse for Electric Power Generation

3.22 If each of the sugar factories were retrofitted with higher steam pressure and temperature boilers (43 Bar/400 Deg. C) and with additional turbo-generating capabilities, the hourly production of surplus electricity, commensurate with process steam, would be 6,165 kWh, 1,070 kWh and 3,870 kWh respectively at Metahara, Wonji and expanded Shoa. This corresponds to 28.2 million kWh, 5.77 million kWh, and 20 million kWh, respectively, or a total of 53.97 million kWh per crop season. This increased power output would not significantly reduce the amount of excess densified bagasse available, as estimated in Chapter 2.

3.23 In addition to the amounts of energy mentioned above, the surplus bagasse in densified form could also be converted into electric power, yielding 35.72 million kWh, 20.8 million kWh and 39.26 million kWh respectively at Metahara, Wonji and expanded Shoa i.e., a total of 95.78 million kWh per crop. The total amount of electric power that could be generated from the combined surplus bagasse and from steam (after meeting process needs) per year therefore amounts to 149.75 GWh.

3.24 However, under the existing and proposed tariff structures, revenue to be derived from the sale of electricity to the public grid, exclusive of the peak power rate, does not justify the capital expenditures needed to equip the ESC factories with high pressure boilers and condensing-extracting turbo-generators. Moreover, if the power generated by the sugar factories were sold to EELPA, the latter would require that they continue power generation year-round i.e. beyond the crop season, otherwise EELPA would have to duplicate their generating capacity. This would involve additional cost.

3.25 Fortunately, densification of bagasse is consistent with the potential future need for additional peak power generation, which has a higher return. Densification allows the buffering of large amounts of potential power-generation fuel in a safe, economical fashion. When required, peak generation could justify the addition of new boilers and condensing-extracting turbo-generators for the purpose of maximizing power generation. In the interim, however, fuelwood substitution remains the more economic option.

Conclusions

3.26 Although the potential use of bagasse in the pulp and particleboard industries as feedstock appears to be economically viable, actual project opportunities will not arise until the 1990s when and if EPPSC has completed a two-step expansion of its paper plant to a capacity of 25,000-30,000 TPA. Should this occur, there would be economic justification for building a 15,000-20,000 bleached bagasse pulp plant which, in turn, would justify the establishment of a suitably-sized depithing/baling facility at the Wonji/Shoa site. However, given the high cost and uncertain implementation of this option, it would not be prudent to pursue depithing at this time.

3.27 Therefore, the most economic immediate opportunity for utilizing excess bagasse lies in converting it to densified fuel for use in households and industry. As discussed in Chapter 2, a substantial amount of surplus bagasse could be obtained from the three sugar factories if a program for energy-conserving factory modifications were implemented. Even without this program, a modest amount of densified bagasse could be produced, using the existing surplus at Shoa. A small densification facility could be installed at Shoa which would not only enable the immediate production of solid fuel but would also allow pilot testing of the actual use of densified bagasse in household stoves, industrial boilers and in the lime kiln at the Wonji/Shoa complex.

3.28 Closely related to the issue of pilot testing is that of the acceptability of densified bagasse for household cooking as its characteristics are different from those of charcoal or fuelwood. Such experience is needed because there is no adequate basis at the moment for deciding whether briquettes or pellets are the more practical product for Ethiopia. However, briquettes are cheaper to produce than pellets ($3.45/t. versus $4.45/t.; refer to Annex 4.) and, for this reason, the pilot plant proposed in the next chapter would utilize a briquettor instead of a pelletizer.

IV. THE PROPOSED PROJECT

Project Objective

4.1 The overall project objectives are: (a) to maximize the surplus of bagasse at the three ESC factories by decreasing their steam consumption and by drying their bagasse using boiler flue gases; and (b) to densify these surpluses to produce a fuelwood substitute. On completion, the Project will generate annually 35,770 tonnes, 20,430 tonnes, and 38,975 tonnes of densified bagasse (bone dry basis) respectively from Metahara, Wonji, and Shoa, a total of 95,175 tonnes.

Project Timing

4.2 ESC plans to complete for the 1989/90 crop: (a) the expansion of the Shoa factory; and (b) an Ethanol and Baker's Yeast plant integrated in the expanded Shoa factory. The objective of ESC is to meet the growing demand of sugar and yeast, and to decrease the use of gasoline by partially substituting the latter with ethanol. The feasibility analysis of the ethanol/yeast facility was completed by SOFRECO in September 1984. The detailed engineering study for the expansion of Shoa is to be completed at the end of 1985, such that tendering may be initiated by mid 1986 to ensure the expansion is completed by September/November 1989. The design of the Shoa expansion with the integrated ethanol/yeast plant is intimately linked to the mission's proposed project. Therefore, a feasibility study for the Project should be initiated by July 1986 to ensure the Project objectives are compatible with ESC's plans and timing.

4.3 In the proposed project, the only unknown at this stage is the type of equipment (a component of the densification system) to be used to densify the surplus bagasse, although the choice has been narrowed to two: a briquettor or pelletizer. The proposed design for the densification system is set out in Annex 2. It is apparent from that design that the final choice of the densifying equipment will have no effect on overall project design, which involves drying, conveying and conditioning before densification and cooling, and conveying and storage after. Consequently, the feasibility study of the proposed project could be carried out while testing of the most promising densifier is being done. For reasons mentioned in para. 3.7, the mission is recommending the installation of a pilot densification system, which will allow the testing of a briquettor to evaluate the practicability and economics of this method of densifying. The pilot plant will be of the same design as that proposed for the large-scale industrial production facility.

4.4 The Project will consist of two phases:

PHASE I: There will be four components to this phase, which should be implemented concurrently:

(a) Pilot Densification Plant - Installation, operation and evaluation of a Densification System which uses a briquettor to densify bagasse;

(b) Market Survey - Assess distribution systems and social/technical acceptability of briquettes (to be financed under proposed Agricultural Residue Briquetting Project);

(c) Cane Top Evaluation - Survey potential supply and cost of using cane tops to replace bagasse (as component of Feasibility Study); and

(d) Investment Feasibility Study (refer to Annex 7).

PHASE II: Factory modifications to expand production of surplus bagasse and large-scale production of densified bagasse in the three existing sugar factories.

The evaluation of the Pilot Plant in Phase I will be completed in June 1988 after a trial which extends through most of a crop period i.e., December 1986 to June 1987. The choice between a briquettor and a pelletizer could then be made in the light of results obtained from the operation of the pilot plant.

Description of Pilot Plant Project: PHASE I

Site Selection

4.5 The factors to consider in selecting the site for the pilot plant are:

(a) a consistent and adequate supply of bagasse; and

(b) distance of the site (or plant) from the largest household market (Addis Ababa) and potential industrial users.

4.6 The best location seems to be at Shoa, for the following reasons:

(a) Shoa has a bagasse surplus averaging 2,546 kg/hr, of which 1,938 kg per hour is diverted to the lime kiln;

(b) Shoa has the highest mechanical time efficiency of the three factories, which means that the output of bagasse is more consistent than the other two factories; and

(c) Shoa is the nearest factory to Addis Ababa, where the market for the densified bagasse to be used as fuel will be tested.

Sizing of the Pilot Plant

4.7 The average industrial briquetting machine on the market has a production capacity of one (1) tonne/hr, and is the recommended unit because of the current quantity of surplus bagasse available at Shoa. To achieve a production rate of 1 tonne/hr or 5,161 tonnes/year, 12% moisture briquettes will require a minimum flow of 1,050 kg/hr of dried bagasse. To produce 1,050 kg/hr of dried bagasse will require a supply of 1,845 kg/hr of mill bagasse to the dryer, leaving a surplus of 701 kg/hr, at 49.9% moisture, available for the lime kiln. With Wonji supplying 775 kg/hr to the lime kiln, the kiln will still be short of 2,230 tonnes/year of wet mill bagasse, which is equivalent to 1,269 tonnes/year of dried bagasse. This amount could be supplied in the form of briquettes from Shoa, leaving a balance of 3,892 tonnes/year for the Addis Ababa market. The burning of the briquettes at the lime kiln will provide the opportunity to test the burning characteristics of the briquettes in an environment which is fairly similar to that of the cement industry, a major potential industrial user.

Pilot Plant Design

4.8 The pilot plant will consist of drying and densification systems, both of which are described in greater detail in sections 4.17-4.24. The drying system, designed with approximately 25% overcapacity, will be capable of processing 2,600 kg/hr of bagasse containing 50% moisture, wet basis, to produce 1,480 kg/hr of 12% m.c. material. Waste boiler flue gases are available on site and will be used as the source of heat for the dryer. The drying system consists of an infeed conveyor, single pass rotary drum dryer fitted with infeed airlock, cyclones fitted with discharge airlocks, induction fan, gas ductings, return conveyor for dried bagasse to boiler, and a conveyor for dried bagasse to the briquetting system. The briquetting system consists of a buffer bin discharging into a variable screw conveyor, briquetter, reject conveyor, accept conveyor, product cooler, cooler fan and cyclone, storage conveyor, and ducting.

Description of the Project: PHASE II

4.9 This phase involves industrial modifications that will result in large-scale production of densified bagasse, as well as installation of full-scale densification systems. The modifications involve decreasing steam consumption, improving the power factor and the drying, conditioning, densifying, storing and reclaiming of bagasse.

Decreasing Steam Consumption

4.10 Steam consumption can be decreased in two ways within the context of this project:

(a) by improving the efficiency of steam utilization in the boiling house;

(b) by improving the power factor of the power distributing systems of the factories.

4.11 Boiling House Steam Utilization Improvements. In general, large economies can be achieved in the boiling house by (a) utilizing 1st, 2nd, and 3rd vapors from the evaporators used for juice heating and pan boiling and (b) replacing filter presses with rotary vacuum filters. Vacuum pans can operate on vapors from the pre-evaporator and/or first body of the evaporator while juice can be heated by using 3rd, 2nd, and 1st vapors in succession. This technique requires more juice heaters than juice heating using exhaust steam only. The degree to which this technique can be applied depends on the evaporator configuration and exhaust steam pressure. Details are presented in Annex 2. In addition, substantial steam savings can be expected by replacing the filter presses at Wonji and Shoa with rotary vacuum filters. This saving is equivalent to 29.37 kg/metric tonne cane processed. In most sugar factories, filter presses have been replaced by rotary filters on account of their:

(a) high operating costs;

(b) high cost of maintenance; and

(c) high cost of materials needed for the operation (cotton filter cloth, tarpaulin cloth, thread, etc.).

4.12 The mission therefore recommends that:

(a) Fourteen (14) filter presses at Wonji be replaced by two 8' diameter x 14' rotary vacuum filters.

(b) Six (6) filter presses at Shoa be replaced by one 8' diameter x 14' rotary vacuum filter at the present grinding rate.

Additional rotary filters will be needed for the factory expansion, and their cost should be absorbed in the overall expansion cost.

4.13 Improvement of Power Factor. The power factors of the three factories are in the range of 0.45 to 0.75, which is much lower than the value at which the back-pressure generators are designed to operate. This low power factor is generally due to motors working under variable load conditions, at levels far below their nominal power. This is particularly true in units such as centrifugals and pumps which are regulated by valves placed on the discharge.

4.14 When ascertaining the power which an alternator is capable of supplying, it must be realized that the permissible power of the alternator decreases at power factors lower than the designated value. The reason for this is that an increase of reactive power requires additional excitation. Therefore, in order to deliver the amount of active power required, and in view of the temperature limitation of the alternator, the reactive power must be generated from a source other than the alternator. For the reasons mentioned in the foregoing, the national grid system is not the recommended source. The preferred alternative is the installation of capacitors and power factor control equipment. The capacitors should be connected very closely to consumers of power in order to relieve circuit breakers and cables. Motors, of about 50 kW and more, should be individually compensated, especially when in continuous operation. However, smaller motors could be compensated in groups or all together.

4.15 In both instances, it is essential to control the switching of capacitors automatically in order to adapt the capacitances to the reactive power requirements and thereby avoid over-compensation. Over-compensation carries danger of self-excitation and consequent voltage increases which, in turn, may endanger the insulation of electrical equipment and machinery. With individual compensation of motors, the capacitor is generally designed to compensate about 90% of the no-load reactive power. A power factor of approximately 0.9 at full load or 0.95 at partial load is thereby achieved. The capacitor is connected in parallel to the motor terminals and switched on and off together with the motor. With larger capacitors damping reactances or resistances are required to limit the current.

4.16 Improving the power factor by utilizing capacitors and power factor control equipment will enable the existing back-pressure generators to supply the active power requirement of the factories with a lower steam flow or, with a given process steam requirement, generate additional active power to accommodate the requirement of added processes, such as drying and densification.

Bagasse Drying and Densification

Generalities

4.17 The main objective of the Bagasse Drying and Densification Process (BDD) is to generate more surplus bagasse for briquetting or pelletization, depending on the results of the pilot briquetting plant which will indicate whether briquetting is more desirable from both a technical and an economic point of view. This objective is achieved by the optimal utilization of the heat contained in the boiler waste flue gases in drying wet mill bagasse. A portion of the dried bagasse is returned to the boiler, thus resulting in higher boiler efficiency which, in turn, results in the generation of larger excesses of bagasse for densification. A technical diagram and detailed description of the process are presented in Annex 4.

4.18 The process consists of three (3) functional systems:

(a) Drying System

(b) Conditioning System

(c) Densification System.

A bagasse reclaim system is also required for Metahara to avoid the burning of fuel oil due to inadequate bagasse handling. These systems are optimized and controlled by an automated closed-loop control system. 9/ The control system is an integrated part of the process which monitors, logs, displays and controls the operation of the specific systems constituting the process.

Drying System

4.19 The drying system consists of an infeed conveyor, disc screen, single-pass rotary drum dryer fitted with infeed airlock, cyclones fitted with discharge airlocks, induced fan, gas ductings, return conveyor for dried bagasse to boiler, a conveyor for moving dried bagasse to the conditioning system, which in turn feeds the densification system.

4.20 The boiler waste flue gases are drawn into the drying system (dryer, cyclones, ductings, and fan) from the existing boiler stacks through a set of dampers which are arranged so that when the drying system is not in use, gases may escape to the atmosphere through the existing boiler stacks. After the start-up of the system, the totality of the dried bagasse exiting the drying system at the cyclones' airlocks is returned to the boiler feed conveyor, where it mixes with the wet mill bagasse flow that was in excess of the amount accepted by the Drying System. The improved moisture content of this mix flows to the boiler, resulting in higher boiler efficiency and in the generation of bagasse in excess of the boiler requirement. At that time, if the desired moisture range required for densification has been reached, a portion of the dried bagasse flow, proportional to the generated surplus, is diverted to the conditioning system ahead of the densification system.

9/ Control system equipment and procedures have been installed in two sugar factories (Hawaii & Mauritius). These installations use pelletizing machines, but the process and control system are essentially unchanged if a briquettor is used instead.

Conditioning System

4.21 The system consists of a variable speed screw conveyor, a conditioning tubular conveyor fitted with steam injectors (urea and molasses injectors if cattle feed is the expected densified product), and a blending mixer, which feeds the densification system.

4.22 The conditioning of dried bagasse, prior to densification, consists of:

(a) homogenizing the bagasse flow, since dried bagasse will easily segregate in various particle-size distributions. The long fibers must be well dispersed in the mix to obtain satisfactory binding strength in the densified form; and

(b) the subsequent treatment of these particles with steam. This preconditioning improves the plasticity and fluidity of the material, resulting in higher throughput at the densifying unit with minimal power consumption.

The material flow and its treatment are regulated by the control system, the latter establishing the relationship between the availability of surplus bagasse generated by the drying system and the production capability of the densification system. Any stoppage of the conditioning system has no effect on the operation of the drying system.

Densification System

4.23 The system consists of a variable screw conveyor, densifier, reject conveyor, accept conveyor, product cooler, cooler fan and cyclone, storage conveyor, and ducting. From the blending mixer, the preconditioned fine bagasse is fed to a densifier through a variable speed screw conveyor, the speed of which is set by the densifier control loop when the latter is activated or by the operator when the loop is inactive, which is the case upon initial start-up. This control loop, when active, maximizes the mill output, and, by preventing choke-ups, reduces down-time.

4.24 Upon initial start-up, the output of the densifier is discharged into a screw conveyor. This conveyor discharges on the dried bagasse conveyor, which returns the product to the boiler feed conveyor. This mode of operation is maintained until the product is of acceptable quality. The densifier discharge is reset to the "ACCEPT" position by the operator once the latter is satisfied with the quality of the densified product. Accepted densified product passes through a cooler before discharging onto an accept conveyor which in turn discharges onto a storage conveyor.

4.25 Ambient air is drawn through the cooler by the cooler fan. The cooler serves three functions; it:

(a) cools the densified product prior to storage;

(b) further reduces the moisture content of the densified product; and

(c) removes most of the fines carried with the densified product.

The pneumatically transported fines are aspirated into the cooler cyclone and from there discharge onto the dried bagasse return conveyor.

4.26 Any stoppage of the densification system has no effect on the operation of the drying system. Dissociating operation of the drying system from that of the densification system is of paramount importance since the latter is mechanically intensive and therefore subject to more maintenance. The efficacy of the drying system results from its continuous operation whenever losses in waste flue gases prevail. The production capability of the densification system is such that it can, after maintenance stoppages, process not only the surplus bagasse currently being generated but also the amount generated when it was off-line.

Bagasse Reclaim System: Metahara

4.27 To eliminate oil burning at the Metahara factory, the boiler must always be given a positive feed of bagasse either from the mill or from the bagasse storage facility. The storage facility and reclaim conveying system must be modified to achieve this. The reclaim conveyor carries bagasse from the storage facility to the boiler feed conveyor, which receives bagasse from the mills [as well], serves the boiler and carries the excess over the boiler requirement to the storage facility. The boiler conveyor enters the top of the storage facility, travels and discharges the excess along the length of the facility.

4.28 The reclaim conveyor, now in a center position below floor level of the storage building, should be relocated to a position near one of the walls along the length of the building. The opposite wall should be extended to about the level of the overhead boiler conveyor. A cross conveyor will be needed to take bagasse from the reclaiming conveyor to the boiler feed conveyor. Two new scraping conveyors will travel along the bagasse pile over the whole length of the building. One, at a right angle to the boiler conveyor, will level the top of the pile; the other will work on the face, pulling bagasse down into the reclaim conveyor. The combined motions will result in a bagasse pile shaped like a trapezoid with a vertical face against the wall opposite the reclaim conveyor and an inclined face from the top of the pile to the reclaim conveyor. The system is such that the boilers will always be receiving bagasse, even if (a) the mills slow down or stop momentarily and (b) steam demand momentarily calls for more bagasse than is then available from the mills, until the whole stock of bagasse is exhausted.

Project Cost - Phases I and II

4.29 The base cost for both phases has been estimated at $12.2 million, of which the foreign component is $10.1 million. The local component is equivalent to 17% of the project cost. Of this, $612,000 would be for Phase I, including $536,000 in foreign costs. Preliminary estimates are given in Table 4.1. At present, DANIDA, the Danish aid organization, has expressed interest in funding this phase through the Bank's Energy I credit to Ethiopia.

4.30 The costs of most project elements are based on those of a similar project recently completed in a Third World country; the rest are based on recent quotations. Each element has been treated as if it were an individually awarded turn-key contract, assuming, for the industrial applications contract for Metahara, Wonji and Shoa, a May 1988 award date and a September 1989 completion date. The award date for pilot plant contracts is assumed to be March 1987, with plant commissioning in December 1987.

Project Organization

4.31 Both phases of the project would be implemented by the Ethiopian Sugar Corporation with the assistance of consultants for:

(a) design and preparation of tender documents for the briquetting pilot plant;

(b) evaluation of pilot plant performance;

(c) preparation of marketing and social/technical acceptability studies;

(d) assessment of cane top utilization;

(e) feasibility studies for the industrial application of the project at Metahara, Wonji and Shoa; and

(f) project design and preparation of tender documents for the industrial application of the project at the three factories.

Table 4.1: PRELIMINARY COST ESTIMATES
(Thousand US Dollars)

	General		Shoa		Wonji		Metahara		
	Foreign	Local	Foreign	Local	Foreign	Local	Foreign	Local	Total
Pilot Briquetting Plant									
Design/Tender	56.00	6.00							62.00
Equipment	455.00	60.00							515.00
Performance Evaluation	25.00	10.00							35.00
Total	536.00	76.00							612.00
Industrial Plants									
Feasibility Study	220.00	16.00							236.00
Design/Tender	390.00	30.00							420.00
Equipment									
Juice Heaters			156.00	57.00	42.70	36.60	191.50	71.90	555.70
Rotary Vacuum Filters			203.50	46.50	407.00	93.00			750.00
Capacitors/PF Controllers			18.12	3.13	14.20	1.42	28.12	3.13	68.11
Bagasse Drying System			1,451.12	334.11	1,198.20	275.84	1,607.00	370.00	5236.27
Bagasse Reclaim System							455.84	104.16	560.00
Densification System			1,220.00	220.00	762.00	136.00	1,220.00	220.00	3,778.00
Total Base Cost	1,146.00	122.00	3,048.74	660.74	2,424.10	542.86	3,502.46	769.19	12,216.07

Disbursement

4.32 The disbursement schedules for Phases I and II, including physical and price contingencies, are provided in Table 4.2:

Table 4.2: DISBURSEMENT SCHEDULE a/
(US$ thousand)

Cost Component	Foreign					Local					Total
	1986	1987	1988	1989	1990	1986	1987	1988	1989	1990	
Engineering/Studies	0.00		100.00	315.00		22.00		40.00			477.00
Equipment	--	455.00	--	898.00	8,077.00	--	60.00	--	197.00	1,776.00	11,463
Total Base Cost	0.00	455.00	100.00	1,213.00	8,077.00	22.00	60.00	40.00	197.00	1,776.00	11,940
Contingencies:											
Physical	0.00	68.25	15.00	181.95	1,211.55	3.30	9.00	6.00	29.55	266.40	1,791.00
Price	0.00	41.86	9.20	111.60	743.08	2.02	5.52	3.68	18.12	163.39	1,098.48
Total	0.00	110.11	24.20	293.55	1,954.63	5.32	14.52	9.68	47.67	429.79	2,889.48
Total Project Cost	0.00	565.11	124.20	1,506.55	10,031.63	27.32	74.52	49.68	244.67	2,205.79	14,829.48
Add: Interest During Construction						0.00	5.51	1.21	14.68	97.73	119.12
Total Financing Requirements	0.00	565.11	124.20	1,506.55	10,031.63	27.32	80.03	50.89	259.35	2,303.52	14,948.60

a/ Includes Phases I and II.

4.33 Project Timetable. A tentative schedule of activities is shown in Table 4.3. For a similar project which was done recently, the elapsed time from contract award to completion was eight (8) months. Thus, these schedules are considered to be realistic and achievable.

Table 4.3: PROJECT TIMETABLE

Year	<---1986							--->	<---1987											--->
Month:	May	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Financing schedule																				
Financing for feasibility study		x																		
Appointment of consultants			x																	
Feasibility study			<-	-	-	-	-	->												
Final report									<-	->										
Project appraisal											<-	-	->							
Loan negotiation													<-	-	->					
Board presentation															<-	-	->			

Year	<---1986							--->	<---1987											--->
Month:	May	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Project schedule																				
1. Pilot plant																				
Selection of consultant for design		x																		
Design/tender documents			<-	-	-	->														
Call for tenders						x														
Receipt of tenders									x											
Award of contract										x										
Pilot plant completion											<-	-	-	-	-	-	-	-	-	->
Pilot plant evaluation	December 1987 to June 1988 (crop season).																			

Year	<---1988							--->	<---1989											--->
Month:	May	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
2. Industrial plants																				
Selection of consultant for design/tender		x																		
Design/tender documents		<-	-	-	-	->														
Call for tenders							x													
Receipt of tenders											x									
Award of contract														x						
Project completion	June 1989 to September 1990.																			

Environmental Impact

4.34 The scrubbing effect of the drying system has been explained in para. 2.12 as well as the effect of burning drier bagasse on mass flow in the boiler furnace. From this, it is expected that the project will decrease overall particulate emissions to less than 5 micrograms/cubic meter, the level of significant impact adopted in the US. The project will have no adverse effect on the neighboring population and infrastructure or on agriculture and wildlife.

V. PROJECT JUSTIFICATION

Introduction

5.1 The need for a non-fossil domestic and industrial fuel to supplement wood, which is becoming increasingly scarce, has been clearly established as a high priority in the UNDP/World Bank Energy Assessment Report. Wood is the traditional fuel for the vast majority of households and for certain light industries. The report indicates that the widening gap between supply and demand is unlikely to be closed even by massive reforestation efforts. The short-term (1992) and long-term (2002) household fuelwood deficits nationwide have been estimated at 9.5 million and 12 million TOE annually. For the southern peri-urban region, which is the nearest concentrated market to the proposed project, the short- and long-term deficit is about 1.1 and 2.2 million TOE. After accounting for petroleum, electricity and new biomass fuel supplies, the deficits in this specific market for the two terms would still be 315,000 TOE and 292,000 TOE. In addition, there is an immediate industrial demand for over 170,000 TOE annually, of which 31,500 TOE could be economically supplied from densified bagasse.

5.2 The present study shows that the local sugar industry could generate as much as 105,000 tonnes of densified surplus bagasse annually through a program of factory improvements. 10/ This is equivalent to about 60,300 TOE or roughly 180,000 tonnes of air-dried wood, a small fraction of the fuelwood demand of the Southern market alone. The Energy Assessment mission found that new biomass fuels, such as densified bagasse, cannot be economically delivered to the northern region from the south-central agriculture and forestry regions. Therefore, the major target market selected by the mission for this new energy source is the southern region and, more particularly, Addis Ababa, with half the southern urban population (1.3 million). The delivered costs in 1985 of firewood, charcoal and kerosene in Addis Ababa are shown in Table 5.1. The economic and financial analyses of the proposed project use these values as their base.

10/ This includes the additional cane to be processed in an expanded Shoa factory but excludes that of the proposed Finchaa project.

Table 5.1: COMPARATIVE FINANCIAL AND ECONOMIC COSTS OF HOUSEHOLD FUELS IN ADDIS ABABA (1985)

	Cost/Unit	GHV	Cost of Energy	Conversion Efficiency	Cost of Useful Energy
	(US¢/kg)	(MJ/kg)	(US$/GJ)	(%)	(US$/GJ)
Financial:					
Eucalyptus	8.3	17.8	4.66	25.1 a/	18.60
Charcoal	43.5	29.0	15.00	30.0 a/	50.00
Economic:					
Kerosene	39.88 b/	36.7	10.87	36.0	30.19

a/ Based on efficiencies in improved wood and charcoal stoves. Current averages are 13% for wood and 24% for charcoal.

b/ Price in ¢/l and GHV in MJ/l.

Source: Mission estimates and Woodfuels Market Price Assessment, April 1985.

Financial Value of Densified Bagasse

5.3 The 1985 nominal retail price of fuelwood is about US$83.75/tonne (17.8 MJ/kg at 20% mcwb). After adjusting for useful energy, at an average stove conversion efficiency of 25% for fuelwood versus 29% for densified bagasse, the $83.75/tonne price of fuelwood translates into a nominal retail price for densified bagasse of $92.44/tonne. As the market may not perceive this difference, the retail price of fuelwood will be taken as the base comparator. This value of densified bagasse ($83.75/tonne) will be further reduced by 20% to reflect market incentives. The reduced value of $67.00/tonne will then be used to determine the attractiveness of producing densified bagasse as a substitute for fuelwood.

Economic Value of Densified Bagasse

5.4 Because the economic value of the most logical comparator fuel -- firewood -- has not yet been determined inter alia through the costing of fuelwood plantations, the economic value of densified bagasse is assumed in this report as the equivalent costs -- after adjusting for differing end-use efficiencies -- of imported fuel oil used in industry and of imported kerosene used in households. Based on the real prices of these fuels, this value comes out to be about $102/tonne as a fuel oil substitute and about $150/tonne as a kerosene substitute. In the case of fuel oil substitution, however, the final economic value was reduced to $81.80 to reflect the cost to industrial consumers of boiler conversion.

Project Benefits

5.5 The project's most obvious benefit to the Ethiopian energy sector would be widespread use of a renewable biomass resource to replace the equivalent of 180,000 tonnes of firewood, or 60,300 TOE of imported fuel oil or 65,900 TOE of imported kerosene. The direct social benefits, provision of domestic and industrial fuel, are self-evident. An indirect benefit would be reduced use of imported fossil fuels that would be needed to supplement hydroelectric power at peak times if more citizens are compelled to use electric cookers for lack of firewood.

Financial Rate of Return

5.6 The base financial cost of the project expressed in 1985 prices is $11.94 million. When physical contingencies of 15% and price contingencies of 8% per annum are added, the total financial cost of the project is $14.95 million. The annual operating cost (O&M, packing, transport and others) is $1.63 million (see Table 5.2). A fifteen (15) year period was taken as the useful life of the project following the commissioning phase in October 1989. The pilot plant would generate revenues from sales of densified bagasse in 1987, 1988 & 1989 while the industrial phase of the Project is being designed and constructed. The operation of the pilot plant would be discontinued when the industrial phase becomes operational in October 1990.

5.7 The financial value of densified bagasse, established at a 1985 level of $67.00/tonne, was assumed to remain constant throughout the life of the Project. The same assumption was made for 'operating cost', 'packing cost' and 'transportation cost' to the Addis Ababa market. The transportation cost from Metahara and Wonji/Shoa to Addis Ababa has been calculated to be respectively $25.25/tonne and $10.00/tonne (refer to Annex 8). The purchase price of packing material was taken at $0.50 per 40 kg bag. It was assumed that 20% of the packing material used in the previous year would be discarded in the current year and replaced with new bags. With these assumptions, the financial rate of return (FRR) was computed to be 30.8% based on the displacement effect of fuelwood.

5.8 The following sensitivity analyses were made:

- Base Case	30.8%
- Project & Production Cost up 20%	19.5%
- Sales Revenues Down 20%	19.2%
- Worst Case	8.3%

The financial rates of return remain attractive, except under the most conservative scenario. If the selling price of bagasse reaches the energy equivalent price of fuelwood, then the rate of return would increase to 44.2% (see Fig. 5.1).

5.9 On average, the Ethiopian Sugar Corporation would generate additional annual revenues of $7.1 million from the sales of densified bagasse. In addition, fuel oil savings at Metahara would amount to $409,000/year. The ESC would also derive financial benefits from the replacement of filter presses with rotary vacuum filters. Without taking into consideration the savings in labor, the benefits from eliminating imported operating materials would amount to $69,000/year. Thus, total annual benefits would amount to $7.5 million, annual costs $3.4 million, and net benefits $4.1 million.

Economic Rate of Return

5.10 The economic analysis was made by considering local and foreign components for each cost item and applying a shadow foreign exchange rate of 1.33 times the official rate. A shadow wage rate of 0.5 times the official wage rate was applied to unskilled labor costs. In the case where the bagasse briquettes are assumed to displace kerosene, the overwhelming detrimant for the economic rate of return (ERR) is the assumed economic value of $150.10/tonne briquettes. This results in an ERR of 93.6% and the following sensitivity to change in costs and revenues:

- Base Case	93.6%
- Project & production cost up 20%	42.2%
- Sales revenues down 20%	42.7%
- Worst case	31.9%

5.11 When substituting for fuel oil at a value of $81.80/tonne briquettes, the economic rates of return under various conditions are:

- Base Case	48.2%
- Project Costs up 20%	36.7%
- Sales Revenues Down 20%	35.3%
- Worst Case	25.2%

The baseline analysis is shown in Table 5.3.

Table 5.2: FINANCIAL ANALYSIS
(Thousand US Dollars)

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
COSTS																			
Engineering/Studies	298.00		140.00	315.00															
Equipment (Installed)		510.00		1094.79	9053.11														
Production																			
Operation		4.53	36.23	208.51	677.25	677.25	677.25	677.25	677.25	677.25	677.25	677.25	677.25	677.25	677.25	677.25	677.25	677.25	677.25
Packing		6.08	43.79	9.73	373.08	988.86	263.93	263.93	263.93	263.93	263.93	263.93	263.93	263.93	263.93	263.93	263.93	263.93	263.93
Transport		5.64	45.15	45.15	592.04	1894.64	1894.64	1894.64	1894.64	1894.64	1894.64	1894.64	1894.64	1894.64	1894.64	1894.64	1894.64	1894.64	1894.64
Other (5% of Eqpt/yr)		25.50	25.50	25.50	547.40	547.40	547.40	547.40	547.40	547.40	547.40	547.40	547.40	547.40	547.40	547.40	547.40	547.40	547.40
Total	-------	41.74	150.67	116.61	1721.02	4108.15	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21
Total Costs	298.00	551.74	290.67	1526.40	11974.13	4108.15	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21	3383.21
BENEFITS																			
Production, tonnes		486	3892	3892	32960	105477	105477	105477	105477	105477	105477	105477	105477	105477	105477	105477	105477	105477	105477
1. Sales Solid Fuel	0.00	32.56	260.76	260.76	2208.32	7066.96	7066.96	7066.96	7066.96	7066.96	7066.96	7066.96	7066.96	7066.96	7066.96	7066.96	7066.96	7066.96	7066.96
2. Savings Fuel Oil (Matahora)					408.70	408.70	408.70	408.70	408.70	408.70	408.70	408.70	408.70	408.70	408.70	408.70	408.70	408.70	408.70
3. Savings Operating Materials					69.06	69.06	69.06	69.06	69.06	69.06	69.06	69.06	69.06	69.06	69.06	69.06	69.06	69.06	69.06
Total Benefits	0.00	32.56	260.76	260.76	2686.08	7544.72	7544.72	7544.72	7544.72	7544.72	7544.72	7544.72	7544.72	7544.72	7544.72	7544.72	7544.72	7544.72	7544.72
NET CASH FLOW	-298.00	-519.18	-29.90	-1265.63	-8888.05	3436.57	4161.51	4161.51	4161.51	4161.51	4161.51	4161.51	4161.51	4161.51	4161.51	4161.51	4161.51	4161.51	4161.51

DATA:

Selling Price Solid Fuel, US$/tonne 67.00

Capital Costs, Industrial Plants

Factory Improvements	7169895
Densification System	3778000
Total for 3 Plants	10947895

INTERNAL RATE OF RETURN: 30.83%
Guess: 90%

Note: FIRR on PILOT PLANT only: -25%

SENSITIVITY OF RATE OF RETURN TO SELLING PRICE

Percent of Wood Market Price	New SP	IRR
100%	85.75	44.24%
90%	75.38	37.66%
*** 80% ***	67.00	30.83% ***

RISK ANALYSIS

Base Case	30.83%
Project Costs up 20%	19.46%
Revenues Down 20%	19.15%
Worst Case	8.27%

Figure 5.1

EFFECT OF SELLING PRICE ON IRR

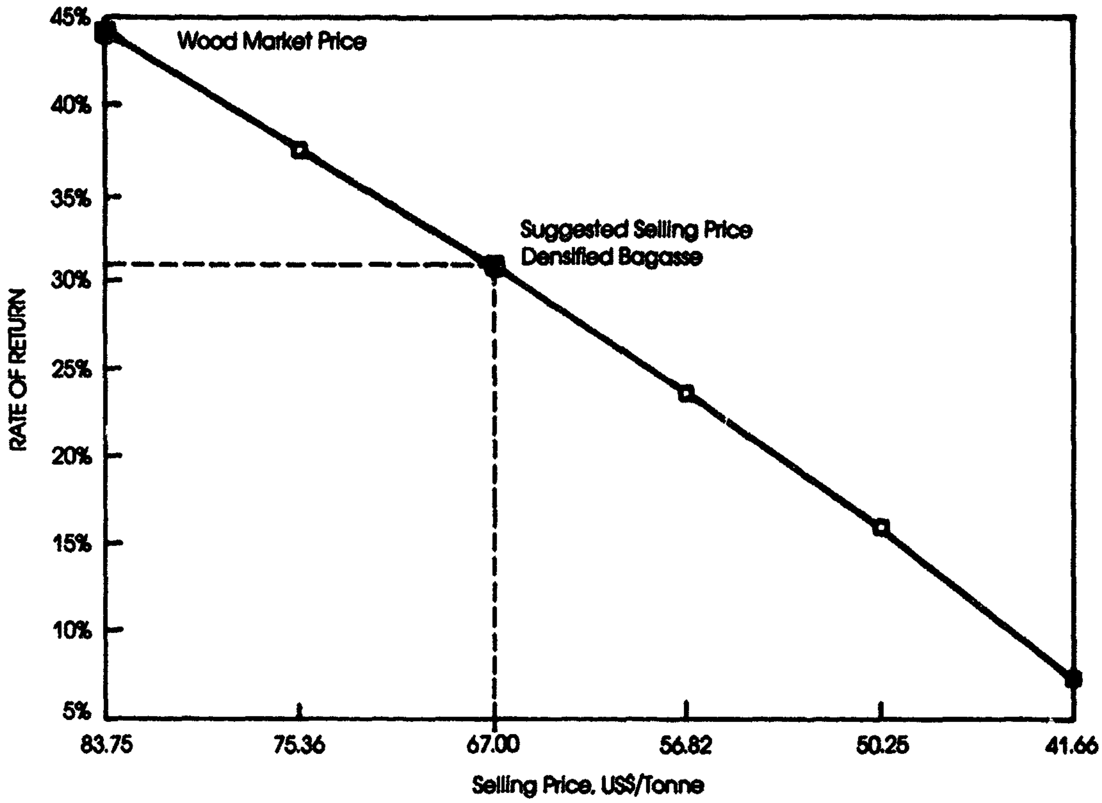

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Table 5.3: ECONOMIC ANALYSIS
(In Thousand Birrs)
1. Based on Economic Value of Product as Fuel Oil Substitute

	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
1. Engineering/Studies	805.40		358.11	867.23						
2. Equipment		1417.85		2880.07	25913.[illegible]					
3. Production										
Operation		5.86	46.87	46.87	359.76	876.19	876.19	876.19	876.19	876.19
Packing		14.13	101.75	22.[illegible]	866.88	2297.69	613.26	613.26	613.26	613.26
Transport		14.96	116.59	116.[illegible]	1528.84	4892.58	4892.58	4892.58	4892.58	4892.58
Others										
(5% of Eqpt/yr)		107.79	389.08	301.[illegible]	1413.54	1413.54	1413.54	1413.54	1413.54	1413.54
Total Costs	805.40	1560.19	1012.40	42[illegible]	29992.13	9480.00	7795.57	7795.57	7795.57	7795.57
BENEFITS										
Production tonnes		486	3892	389[illegible]	[illegible]60	105477	105477	105477	105477	105477
1. Sales Solid Fuel		109.45	876.49	876.[illegible]	[illegible]122.71	23753.80	23753.80	23753.80	23753.80	23753.80
2. Savings Fuel Oil										
(Metahara)				1309.[illegible]	[illegible]14	1309.214	1309.214	1309.214	1309.214	1309.214
3. Savings in Imported										
Operating										
Materials					[illegible]	190.13	190.13	190.13	19[illegible].13	190.13
Total Benefits	0.00	109.45	876.49	876.49	8922.05	[illegible]53.14	25253.14	25253.14	25253.14	25253.14
NET CASH FLOW	-805.40	-1450.74	-135.91	-3358.01	-21070.0	15773.14	17457.57	174[illegible].57	17457.57	17457.57

	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Engineering/Studies									
2. Equipment									
3. Production									
Operation	876.19	876.19	876.19	876.19	876.19	876.19	876.19	876.19	876.19
Packing	613.26	613.26	613.26	613.26	613.26	613.26	613.26	613.26	613.26
Transport	4892.58	4892.58	4892.58	4892.58	4892.58	4892.58	4892.58	4892.58	4892.58
Others									
(5% of Eqpt/yr)	1413.54	1413.54	1413.54	1413.54	1413.54	1413.54	1413.54	1413.54	1413.54
Total Costs	7795.57	7795.57	7795.57	7795.57	7795.57	7795.57	7795.57	7795.57	7795.57
BENEFITS									
Production tonnes	105477	105477	105477	105477	105477	105477	105477	105477	105477
1. Sales Solid Fuel	23753.80	23753.80	23753.80	23753.80	23753.80	23753.80	23753.80	23753.80	23753.80
2. Savings Fuel Oil									
(Metahara)	1309.214	1309.214	1309.214	1309.214	1309.214	1309.214	1309.214	1309.214	
3. Savings in Imported									
Operating									
Materials	190.13	190.13	190.13	190.13	190.13	190.13	190.13	190.13	190.13
Total Benefits	25253.14	25253.14	25253.14	25253.14	25253.14	25253.14	25253.14	25253.14	25253.14
NET CASH FLOW	17457.57	17457.57	17457.57	17457.57	17457.57	17457.57	17457.57	17457.57	17457.57

DATA:

Exchange Rate, Birr/US$: 2.07

Border Price of Fuel Oil, US$/tonne 281.00

Economic Value of Densified Bagasse, US$/tonne

	Economic Value of Densified Bagasse, US$/tonne	INTERNAL RATE OF RETURN
As Kerosene Substitute	150.10	93.60%
As Fuel Oil Substitute	81.80	48.18%

Shadow Factors:

Unskilled Labor 0.50

Foreign Exchange 1.33

SENSITIVITY

Base Case:	48.2%
Project Costs up 20%:	36.7%
Sales Revenues Down 20%	33.3%
Worst Case:	25.2%

Project Risks

5.12 The risks of the project are minimal from the institutional, technical and commercial viewpoints. The continuity of the sugar industry in Ethiopia is indicated by the Ethiopian Sugar Corporation's pursuit of the Finchaa sugar project in addition to the expansion of the existing Wonji/Shoa complex and its venture in the alternative energy field, i.e., the Shoa Alcohol Project.

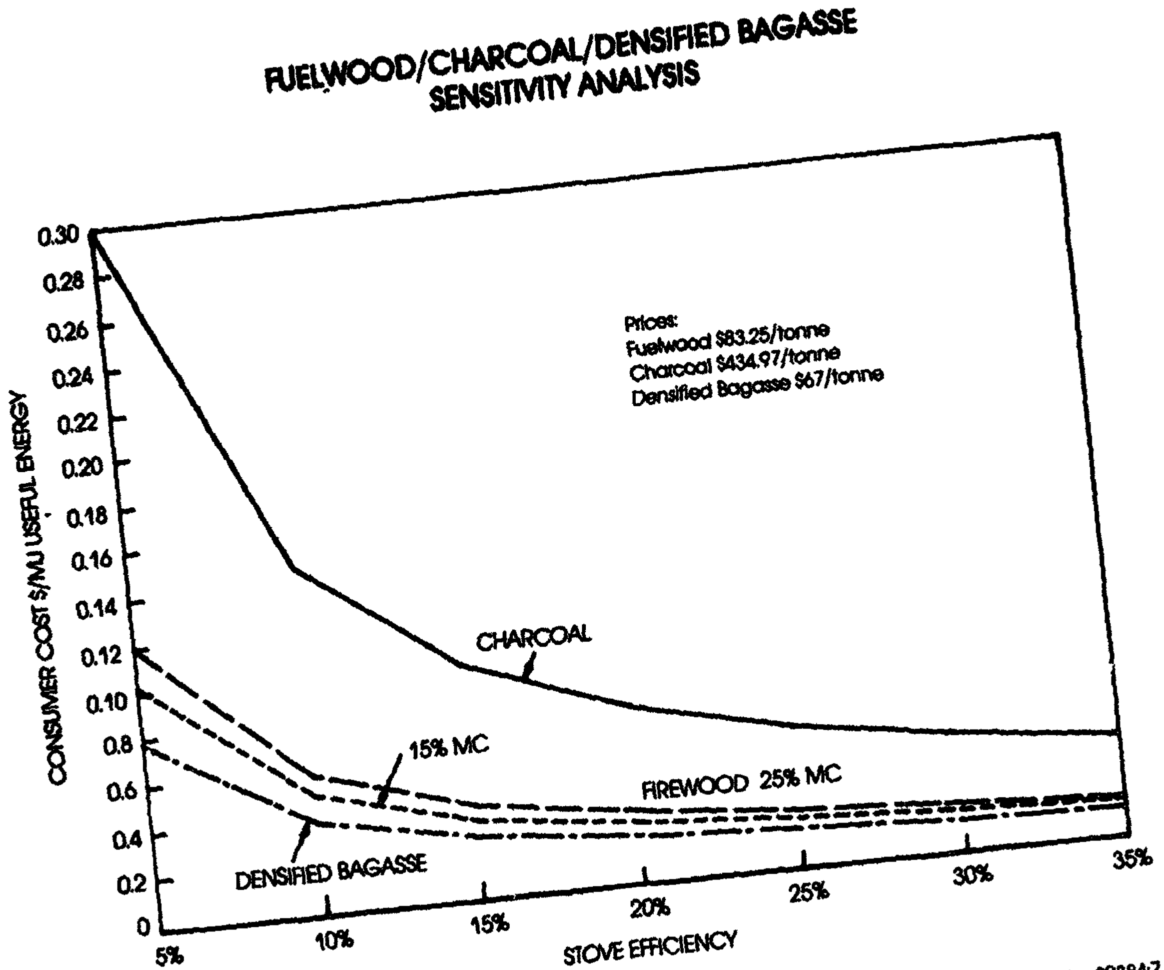
5.13 The managerial and technical capabilities of the Ethiopian Sugar Corporation staff are evidenced by the standard of the sugar plantations which are at a comparable level to that found in other developing countries. The operating staff has already coped with some forefront technologies such as cane diffusion and self-adjusting mills, and therefore should have no difficulty with some of the novel aspects of the project. Moreover, ESC has an ongoing training facility as well as a fabrication facility that has proven itself, e.g., in fabricating evaporating vessels such as vacuum pans.

5.14 The technical risks are limited since most of the components of the project have been proven in this type of industrial application e.g., juice heaters, rotary filters and power factor correctors. The bagasse drying and densification component has been industrially tested in Hawaii since 1981, and most recently in Mauritius during September-October 1985. The method of densification used in these two facilities is pelletization. The pilot plant component of this project will provide an opportunity to test briquetting as the preferred method of densification and to evaluate its cost effectiveness. The final selecton of densification methods will have no significant impact on the implementation of the industrial phase of the project.

5.15 The main commercial risk would be the acceptance of densified bagasse as a household substitute fuel for firewood and charcoal, though the substitution for fuel oil and fuelwood in the light industries is practical and therefore could provide alternative users. Since most of these industries are supervised by the Ministry of Industry, it could develop policies to promote immediate adoption of this alternative. Substitution of fuel oil in these industries by densified bagasse will further enhance the economic benefits of the project. On the household side, stove efficiency could affect the competitiveness of bagasse. However, Fig. 5.2 indicates that densified bagasse remains competitive over a wide range of stove efficiencies.

5.16 In view of the manageability of the identified risks, the project's high economic and financial benefits, and the Government's recognition of the pressing problems in the energy sector, project implementation should be initiated at the earliest possible date.

Figure 5.2



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DESCRIPTION OF SUGAR MILL OPERATIONS AT WONJI, SHOA AND METAHARA

The Factories

The three factories operate on a 24 hour/day, 7 days/week basis during a period of 250 days which extends from October to June. Maintenance of equipment is carried out monthly during planned shutdowns of 8-12 hours. Cleaning of juice heaters and evaporators is done during normal operation of the factory since these factories are fitted with spare units.

Metahara

This factory has a crushing capacity of 5,000 TCD. Cane preparation and juice extraction is performed by two preparation/milling trains and one diffuser. Train A consists of two sets of knives, one mill, a de Smet diffuser, and two dewatering mills. Train B consists of five FCB self-adjusting mills. All the mills are driven by steam turbines through appropriate reduction gearing. The extracted juice is weighed then heated to 70-75 Deg. C, limed for defecation and sulphited for discoloration. It is further heated to about 100 Deg. C before being sent to the clarifiers. Juice heating is effected in a battery of heaters arranged in such a way that one or two heaters at a time can be by-passed for cleaning. The heating medium is vapor bled from the 2nd effect of the evaporator for temperatures up to 75 Deg. C. and vapor bled from the 1st effect for temperatures up to 100 Deg. C. There is also a preliminary cold juice heater utilizing vapor from the last effect of the evaporator. After the juice has subsidized in the clarifier, the clear portion having a brix of 16.5 is sent to the evaporator for concentration to approximately 65 Deg. Brix. The mud from the bottom of the clarifiers is filtered in two Oliver Rotary Vacuum filters, the filtrate is returned to the weighed juice and the filter cake is discarded. This filter cake can be used as fertilizer.

Evaporation of the clear juice is effected in two batteries of multiple effect evaporators. The vessels of the evaporators are arranged in such a way that one or two vessels can be shut down and by-passed for cleaning.

The 65 Deg. Brix syrup is sulphited for further discoloration before being sent to the sugar boiling house.

The three strikes boiling system is used in Metahara. By this system the exhaustion of molasses is effected in three steps with runnings from the centrifugals boiled back using 2nd strike magma as seed. The three strikes are labelled A, C and D. A is the highest purity strike from which commercial sugar is produced, D is the lowest purity strike which give the final exhausted molasses and C is the intermediate purity strike from which the magma seed is obtained.

Batch type and continuous centrifugals are used to purge massecuite and obtain sugar. The commercial sugar is dried before being bagged and stored or dispatched to sales units.

Steam for prime movers and process is produced by burning mill run bagasse in four boilers having a total capacity of 125 T/hr. In addition, fuel oil at the rate of 2000 tonnes per crop is burned to supplement bagasse shortages during mill stoppages and when the boiler steam pressure drops; as a result there is some bagasse surplus, but this can be considered as being an artificial situation caused by incidental oil burning.

Electricity generation for factory use is provided by two Brown Boveri multi-stage turbo-alternators of 3180 kW; a third unit of the same size is kept as stand-by.

The main problem areas in the Metahara Sugar Factory are sugar centrifugals, bagasse carriers, diffuser and condenser water shortages. The sugar centrifugals are old and many of them are often out of use causing congestion in the boiling house and crystallizers up to the point that the mills have to be stopped.

Bagasse carriers cause up to 10 hours of mill stoppages per month due to worn out chains and sprockets.

Diffuser capacity had to be reduced from 3000 to 2500 TCD as a result of operational difficulties in the diffuser itself and in the mills of A tandem.

Condenser water shortage is due to defective electrical distribution to the river pumping station and to problems in the piping system. This water shortage impedes the proper operation of vacuum pans and evaporators thereby decreasing their capacity.

2.1 Plans for the Future

The agricultural area for Metahara is expected to increase from its present area of 8507 hectares to 10,300 hectares. Factory capacity will have to be increased accordingly but no definite plans have been made so far.

Wonji

The Wonji factory has a crushing capacity of 1420 TCD. Prior to milling the cane is prepared by one set of cane knives and one Unigrator Shredder, both machines are driven by electric motors. The milling train consists of one Fulton 2-roller crusher and four 3-roller mills, all being driven by steam engines. Clarification, discoloration and heating of juices are similar to the process carried out at Metahara. However, there is no preliminary heating of cold juice with the last evaporator effect vapor. Evaporation of the clear juice to 64 Deg. Brix is done in one set of multiple effect evaporators with vapor recompression at the first effect. Mud filtration is done by old plate and frame filter press; the clear filtrate is sent to the evaporators and the filter cake discarded as at Metahara. The syrup is sulphited for further discoloration.

Boiling of sugar is effected by the four strike method. The A and B strikes produce the commercial sugar, the C sugar is used as seed for the A & B strikes and the D sugar is melted and reprocessed.

Batch-type centrifugals are used for curing the sugar. Commercial sugar is dried before being bagged.

The steam generation station consists of five old boilers -- one of which is on stand-by -- with step grate furnaces and manual bagasse feed. However, no oil is normally burned during the crop and there is a bagasse excess of 3,000 tonnes per annum which is compressed in bales having an average size of 500 x 500 x 750 mm. Part of this baled bagasse is used for factory start-up. In some instances where bagasse percentage in cane is low and there are frequent stoppages, oil is occasionally burned.

Electrical energy is generated by one new 1585 kw Stal multi-stage turbo alternator. Another identical unit is on stand-by.

The main problem areas in Wonji are the bagasse conveyors, the mills, mud filtration and old centrifugals.

The mills and bagasse conveyors cause frequent stoppages which is detrimental to bagasse-saving.

Mud filtration is carried out in plate and frame filter presses. This operation is labor-intensive and a considerable amount of money is spent every year for the purchase of filter cloth and thread. Filtration of mud in plate and frame filter presses consumes a relatively large amount of steam.

The centrifugals are old and require constant maintenance and spare parts. Quotations have been requested for the replacement of the existing centrifugals with modern units.

Shoa

This factory has a cane crushing capacity of 1650 TCD. Cane preparation before milling is performed by two sets of cane knives. Cane crushing, juice clarification and discoloration as well as juice heating and evaporation are similar to what is done in Wonji. Regarding mud filtration, there is a battery of plate and frame filter presses as well as a rotary vacuum filter.

Sugar boiling and massecuite purging is effected in the same way as in Wonji.

Shoa has three B & W 15 tonnes MCR boilers one of which is stand-by. The furnaces are of the step grate type and bagasse feed is manual. A bagasse surplus of approximately 13,000 tonnes/yr is obtained, 10,000 tonnes of which is used in the lime kiln which produces the lime required for the three sugar factories for defecation of the juice.

As with Wonji, mills and bagasse conveyors are major cause of stoppages. The clarifier is under capacity and is sometimes the cause of stoppages.

Plans are being made to increase the crushing capacity of Shoa from 1650 to 4100 TCD. An Ethanol Distillery as well as a Bakers Yeast plant are planned for implementation in Shoa.

Future Industry Prospects

The sugar demand is expected to grow to approximately 560,000 tons in 1995/96, this increase being due to both an increase in population was well as an increase in per capita consumption.

In order to satisfy this demand, plans are already being made to build a new sugar factory at Finchaa, 345 kms northwest of Addis Ababa. The Finchaa sugar factory should be operational in 1989/90 with a production capacity of 84,000 tons of sugar per annum. Annual production of 125,000 will be reached in 1995/96. An ethanol distillery of 8,000 tonnes capacity expandable to 12,000 tonnes per annum will be annexed to Finchaa (See Annex 3).

As already stated, the capacity of the Shoa factory will be increased by 2.5 times its present capacity.

According to demand and supply projections, a 5th sugar factory will have to be commissioned in 1990/91.

DETAILED ENERGY IMPROVEMENTS FOR INCREASING SURPLUS BAGASSE PRODUCTION

This annex provides technical details on:

(1) factory steam utilization under existing conditions;

(2) factory electrical energy utilization under existing conditions;

(3) improving steam generation efficiency by bagasse drying;

(4) making boiling house improvements;

(5) reducing process steam requirements by boiler and electrical improvements;

(6) improving electrical power factors;

(7) capturing unburnt particles in the flue gases; and

(8) wet vs. dried surplus bagasse.

Steam Utilization Under Existing Conditions

The steam flow distribution pattern of the three factories is represented by the following flow-diagram and Table 1.

(HIGH PRESSURE HEADER)

OTHER USE	MILL DRIVES	BOILER AUXILIARIES	BACK PRESSURE GENERATOR (B.P. GEN)	PRESSURE REDUCING VALVE (P.R.V.)

(LOW PRESSURE HEADER)
(EXHAUST STEAM TO PROCESS)

It is noted from this distribution pattern that a fairly large percentage of the process steam is contributed by the pressure reducing valve (P.R.V.). But most of the high pressure steam from the boiler flows through steam engines and/or turbines (prime movers) to provide the driving force for the machinery. This steam, expanded through the prime movers to a lower pressure (exhaust pressure), is then used for heating where it is condensed. The exhaust pressure level is established by the evaporation rate (kg water evaporated per hour and per square meter) and more particularly by the evaporation vapor, used for final juice heating, which must be at a certain minimum pressure to bring the juice to the required temperature; this minimum vapor pressure establishes the level of the exhaust pressure. The P.R.V., acting as a by-pass, supplements the heating energy provided by the prime movers' exhaust such that the process requirement is satisfied.

Table 1: STEAM GENERATION AND UTILIZATION

Steam	Metahara		Wonji		Shoa	
	(kg/hr)	(%)	(kg/hr)	(%)	(kg/hr)	(%)
Mill Drives	22,109	21.3	5,323	13.7	7,095	21.4
Boiler Aux.	-	-	458	1.2	929	2.8
B.P. Generator	41,336	39.7	16,197	41.7	14,606	44.0
P.R.V.	36,665	35.3	13,860	35.7	7,251	21.8
Total Process	100,110	96.3	35,838	92.3	29,881	90.0
Other Use	3,871	3.7	2,966	7.6	3,313	10.0
Boiler Output	103,981	100.0	38,804	100.0	33,194	100.0

Note: "Other Use" refers to process uses where exhaust steam is not the most suitable medium, e.g., the steam requirement of filter presses, pan and centrifugal steaming, etc.

Optimal utilization of steam is achieved when a balanced relationship prevails between the steam demand for driving force and the steam demand for heating. But, when the prime movers utilize more high pressure steam, thereby producing more exhaust steam than is necessary for processing, there will be an excess of exhaust steam which will cause the exhaust pressure to rise above the pre-established level whereby the exhaust pressure control system will open the relief valve(s) resulting in exhaust steam being blown into the atmosphere until the pre-defined exhaust pressure is re- established.

Blowing off of exhaust steam results in direct and indirect heat losses; the direct loss being the available heat in the steam and the indirect loss being the replacement of a portion of the hot condensate, equivalent to the lost amount of steam, by cold make-up water for boiler feed. This cold make-up decreases the steam to bagasse ratio, thereby decreasing the amount of surplus bagasse and, in the absence of a surplus, the use of supplemental fuel.

At none of the three factories under consideration is there any evidence of exhaust steam blowing off into the atmosphere. This observation is verified by the simulations which show that more than 30% of the steam flows from the high pressure (H.P.) header into the low pressure (L.P.) exhaust header through a P.R.V. which maintains the exhaust pressure. This P.R.V. also acts as a by-pass around the back pressure generator. This feature is essential in avoiding the direct relationship that exists between back-pressure steam and the power generated to satisfy the internal electrical energy requirement when the alternator is not connected to the grid, as is the case for the three factories. With the B.P. generator not coupled to the grid, the governor of the turbine has to maintain the speed, i.e., frequency of the generator, at a constant level by adjusting the steam quantity admitted to the power requirements. Moreover, power being the dominant factor, the pressure of the exhaust steam has to be maintained at a constant value by flowing steam through a by-pass (P.R.V.) or a blow-off valve. The latter alternative, as previously mentioned, is detrimental to the objective of generating surplus bagasse.

Electrical Energy Utilization Under Existing Conditions

During the cane grinding season, most of the electrical energy for the factories, plantation villages, staff housing, clubs and administrative quarters is produced from bagasse. At Wonji, the power requirement for the plantation villages, hospital, and confectionery plant are purchased from the national grid. At Metahara, the factory contributes 470 to 500 kW to the domestic load during the cane grinding season. During the off-season, Metahara purchases some 300,000 to 340,000 kWh for domestic purposes, at a rate of Br. 0.084 to 0.086/kWh, inclusive of demand charges. The hourly generation at Shoa factory, 1,251 kWh, provides a portion of the irrigation power requirement during the cane grinding season. The cane fields are mostly irrigated by gravity from a combination of canals radiating from the river, syphons from the canals, and furrows in the field. Where the fields are on higher ground than the river bed, pumps are used to lift the water into the canals.

At Metahara, from a total of 8,800 hectares, some 1,150 hectares use lifting pumps. These pumps presently consume 2,405 kWh per hectare/year according to the records of purchases for the period December 1983 to August 1984. The lifting pumps are utilized during 11 months/year. The hourly energy consumption is 345 kWh with a maximum demand of 400 kW. This energy is purchased from the national grid at a rate which averages Br. 0.0904 per kWh, inclusive of demand charges.

Metahara is presently installing two additional pumps to the existing six units. Therefore, the future energy needs are expected to increase to approximately 3,850 kWh per hectare/year, i.e., an hourly consumption of 552 kWh for the 11 month period, with a maximum demand of 640 kW. The annual purchase will then be 4.425 GWh versus the present purchase of 2.765 GWh.

The Wonji/Shoa complex of 7,000 hectares uses eight lift pumps with an installed capacity of 720 kW. The hourly consumption of energy for 10 months (excluding the rainy period, July and August) has been estimated at 376 kWh with a maximum demand of 435 KW; i.e., 2.75 GWh per year at Br. 0.1838 per kWh.

This complex will be increased to 4,600 hectares by 1990, and assuming that this new area would require lifting pumping capability, then the additional annual energy requirement would be approximately 11 GWh or an hourly consumption rate of 1,500 kWh, with a maximum demand of 1,750 kW.

Table 2 demonstrates that the three factories are self-sufficient in power needs during the cane grinding season. Furthermore, presently between 20 to 35% of the H.P. steam is, under average conditions, routed through the P.R.V. station.

Table 2: ELECTRICAL ENERGY GENERATION AND UTILIZATION
(Cane Grinding Season only)

	Metahara	Wonji	Shoa
	(kWh)	(kWh)	(kWh)
ELECTRICAL			
Generation	3,900	1,103	1,251
Internal Use	3,900	1,103	1,251

If the flow through the P.R.V. was instead routed through the B.P. Generator the additional electrical energy generated hourly by the three factories would be:

(a) 3,459 kWh at Metahara
(b) 944 kWh at Wonji
(c) 621 kWh at Shoa

But, as previously mentioned, this additional energy could be made available for irrigation only if the factory system was tied to the national grid; otherwise, the P.R.V. is needed to maintain constant generator speed. The plantations (factories and fields) would then be totally self-sufficient in meeting their present and future electrical energy needs from bagasse during the cane grinding season using only bagasse.

Improving Steam Generation Efficiency

Table 3, derived from simulations, shows the levels of efficiencies and losses now prevailing at the three ESC factories.

Table 3: PRESENT LOSSES IN STEAM GENERATION

Source of Loss	Unit	Wonji	Shoa	Metahara
Boiler Efficiency	%	55.52	64.46	58.21
Boiler Losses				
in flue gas	%	31.88	27.72	29.05
other	%	12.60	7.82	12.74
Boiler Losses in terms of Bone Dry Bagasse				
in flue gas	tonnes	42,353	12,721	12,295
other	tonnes	16,739	3,589	5,392

From the foregoing, it is apparent that substantial losses occur at the steam generating units and improvement in their combustion efficiencies would generate a surplus of bagasse.

Economizers and air preheaters have traditionally provided the means for improving boiler efficiency by extracting heat from boiler waste flue gases. The economizer is usually installed in series with the air preheater. However, there are drawbacks and limitations to their use. One of the main limitations is in the exit temperature of the flue gas leaving the air preheater-economizer system. Whereas the dew-point of bagasse boiler flue gases is generally in the range of 140 to 65 Deg. C., the economizer and/or air preheater are usually designed for exit temperatures of 125 to 150 Deg. C. The reason for this is to avoid pockets of flue gases reaching dew-point temperatures which can cause severe corrosion problems, especially if, for reasons of economy, the economizer tubes are made of carbon steel. Furthermore, to reach much lower temperatures than 125 to 150 Deg. C. would require a much larger heat-exhange surface which would increase the cost and cause increased friction losses both in the flow of water inside and the flue gases outside the tubes, thus incurring additional pumping and industrial draft fan costs.

The traditional air heater-economizer system being fully incorporated into the boiler is also not very flexible and further does nothing to recapture the unburnt or partially burned particles that are entrained in the flue gases. The entrainment of these particles for a given boiler is proportional to the velocity of the combustion gases, which in turn depend on their volume. Burning wet bagasse (48 to 52% moisture) requires a larger amount of combustion air which, added to the large volume of vapor generated in the furnace through the drying of wet bagasse, causes high velocities that increase the amount of fuel particles lost through the stack.

On the other hand, the use of a bagasse dryer as an additional means of recovering waste heat offers many advantages: (1) permitting a considerably higher heat recovery; (2) reducing the volume of flue gases;

(3) lowering their dew-point and capturing most of the entrained particles (which, in any case, are less because of reduced velocities of the combustion and flue gases). Exit temperatures very near the dew-point can safely be reached because properly designed drying systems lend themselves to precise control without interfering with the boiler operation. The use of cyclones in the drying system also allows the capture of most entrained particles (up to 95%) as proven in Hawaiian sugar mills, and in the Bagapel project at the Beau-Champ factory in Mauritius.

Finally, logistical considerations favor the installation of dryers in the ESC factories as it would be difficult and costly to increase the surface area of the existing heat exchangers because of limited space, and the difficulty of installation in the existing boilers. The addition of drying systems at the ESC factories would considerably increase the heat recovery from flue gases by lowering the exit temperature to a few degrees above the wet-bulb temperature. Also, since only a portion of the dried bagasse would be used by the boilers, their efficiencies would be increased which, in turn, would result in a larger surplus of bagasse.

Therefore, the installation of a dryer at each of the factories is recommended instead of augmenting the existing heat recovery systems of the present boilers. Moreover, the impact of the dryer exit gas on the environment would be significantly improved due to the scrubbing effect and significantly lower exit gas temperature.

In the case of Shoa, where a new boiler will be required for the anticipated expanded grinding rate, a dryer is still recommended even though this boiler is expected to be designed with state of the art air and water preheaters and a low gas velocity furnace. In this case, the inclusion of an air preheater and economizer is necessary and financially viable to continue power generation past the grinding season for the purpose of supplying electrical energy to the neighboring paper facility. Also, at times when the milling section is down and there is no bagasse to feed the dryer, it is essential to minimize the flue gas temperature to maintain as high a boiler efficiency as possible.

Boiling House Improvements

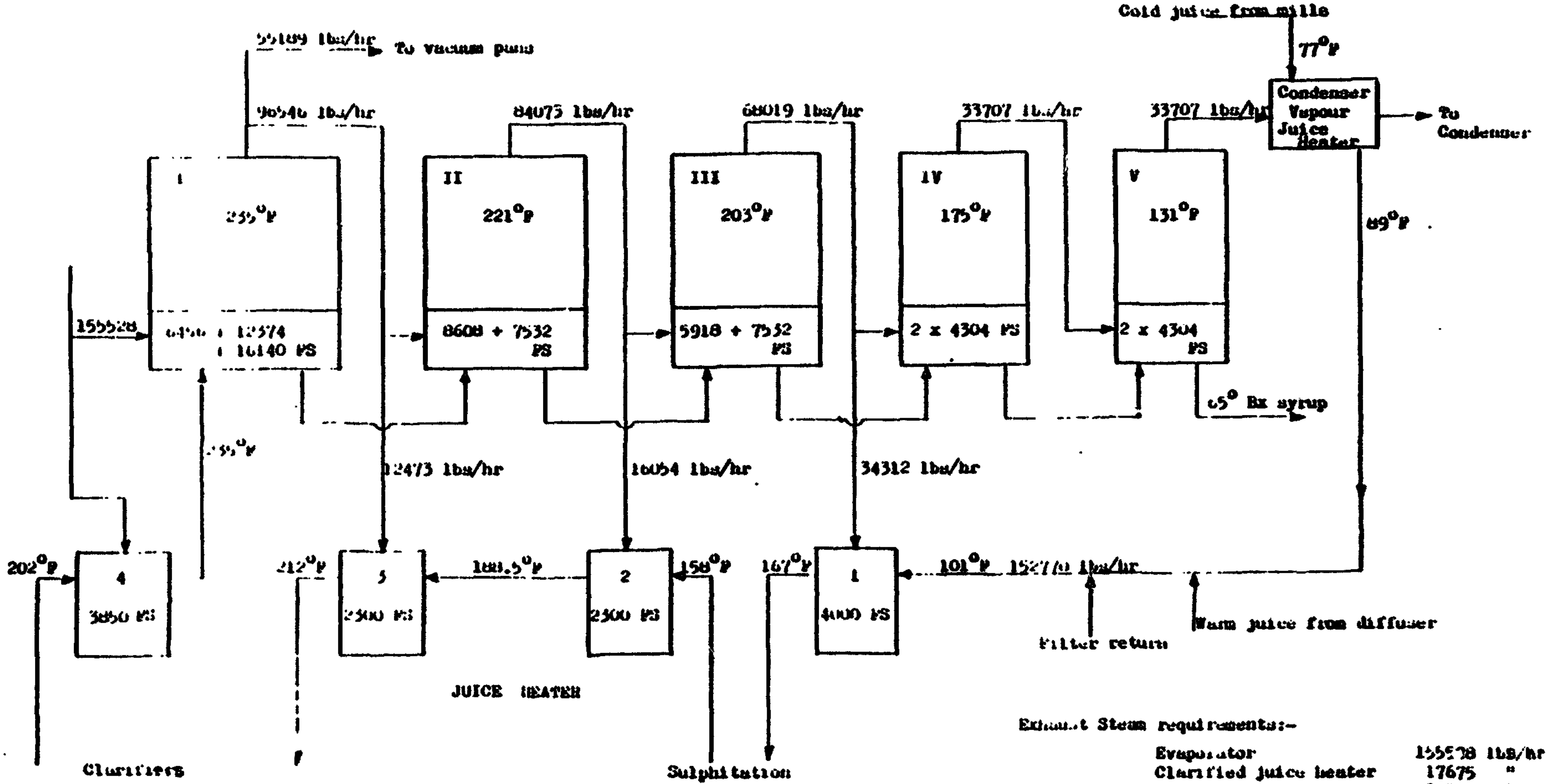
The mission recommends the following improvements at each of the factories:

Metahara (refer fig. A2.1)

3 x Juice Heaters of 2,000 sq.ft. on 3rd Vapor
5 x Juice Heaters of 1,150 sq.ft. on 2nd Vapor
1 x Juice Heaters of 3. 850 sq.ft. on Exhaust

Fig A2.1 - EVAPORATOR AND JUICE HEATER ARRANGEMENT - METAHA

QUINTUPLE EFFECT EVAPORATOR



Exhaust Steam requirements:-

Evaporator	155528	lbs/hr
Clarified juice heater	17675	"
Diffusion	21702	"
Sugar drying	1770	"
Total ..	196675	lbs/hr

Wonji (refer fig. A2.2)

3 x Juice Heaters of 725 sq. ft. on 3rd Vapor
4 x Juice Heaters of 500 sq. ft. on 2nd & 3rd Vapor
1 x Juice Heaters of 1,500 sq. ft. on Exhaust

Shoa (refer fig. A2.3)

5 x Juice Heaters of 1,050 sq. ft. on 3rd & 4th Vapor
3 x Juice Heaters of 1,900 sq. ft. on 1st & 2nd Vapor
1 x Juice Heaters of 2,900 sqft on Exhaust

Reducing Process Steam Requirements

Assuming that the prime movers are being operated at their optimal efficiencies, the flow of steam to these prime movers cannot be reduced for a given grinding rate, the load on mill drives being proportional to the rate of fiber crushed per hour. On the other hand the load on the B.P. generator is related to the amount of cane processed for a given set of conditions. If the amount of exhaust from the mill as well as other prime movers and the B.P. generator is not sufficient to meet the process steam demand of the boiling house, it is made up by the P.R.V. It is therefore clear that reducing the process steam demand would reduce the amount of steam flowing through this P.R.V. and result in an overall steam economy which in turn will tend to create a bagasse surplus.

5.2 The improvements in heating requirements contemplated by the mission would substantially reduce the process steam requirement from the present level to the values shown in the Table 4. The replacement of filter presses by rotary vacuum filters at Wonji and Shoa would also bring a significant saving in steam requirement under the category 'other uses'.

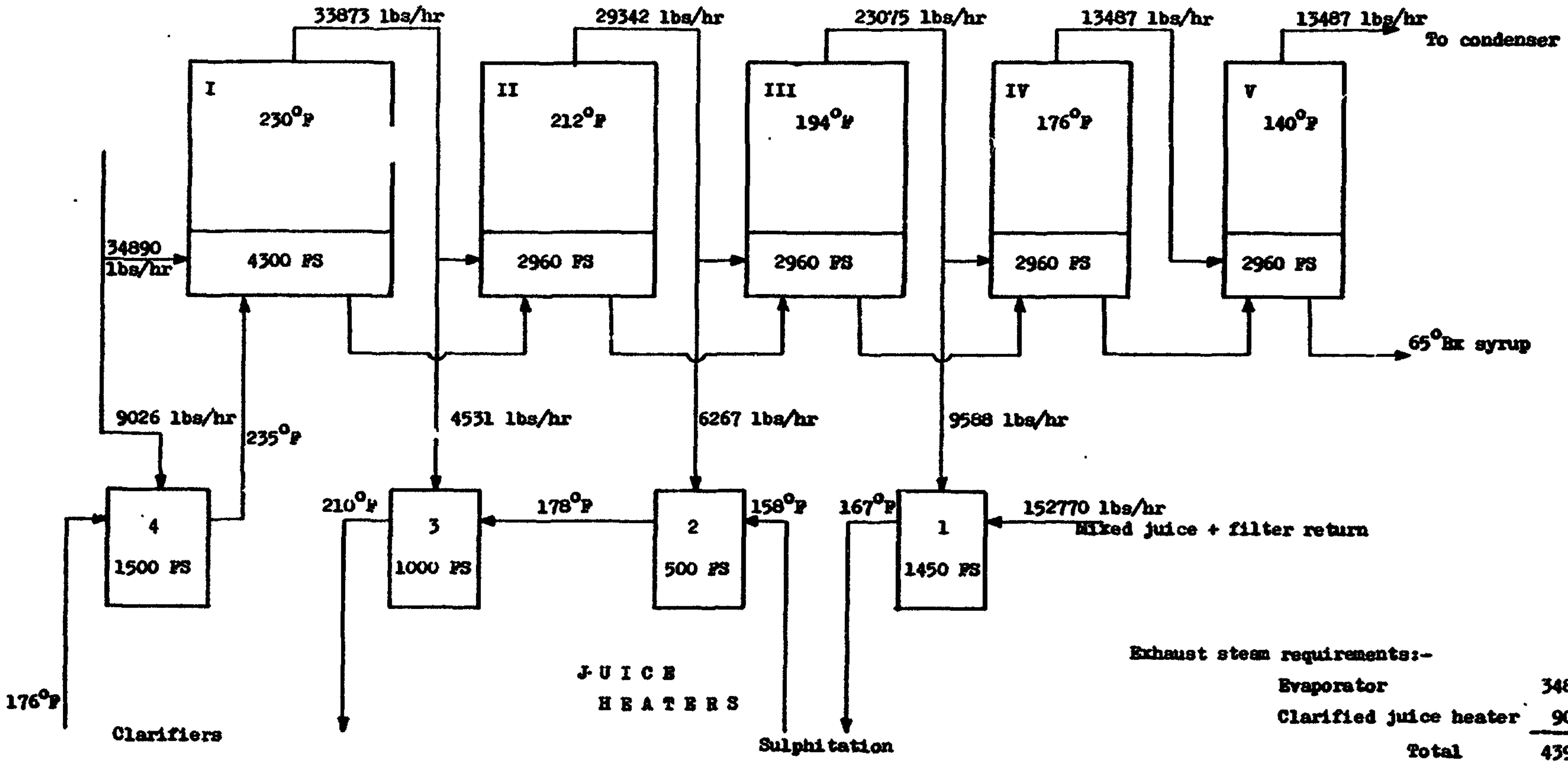
Table 4: STEAM REQUIREMENTS IN IMPROVED FACTORIES

	Unit	Metahara	Wonji	Shoa
Steam				
process use	kg/tch*	435.00	377.00	87.50
other uses	kg/tch	18.63	18.63	18.63
Total	kg/tch	453.63	395.63	406.13

* t.c.h. = metric tons of cane per hour

Fig. A2.2- EVAPORATOR AND JUICE HEATERS ARRANGEMENT - WONJI

QUINTUPLE EFFECT EVAPORATOR

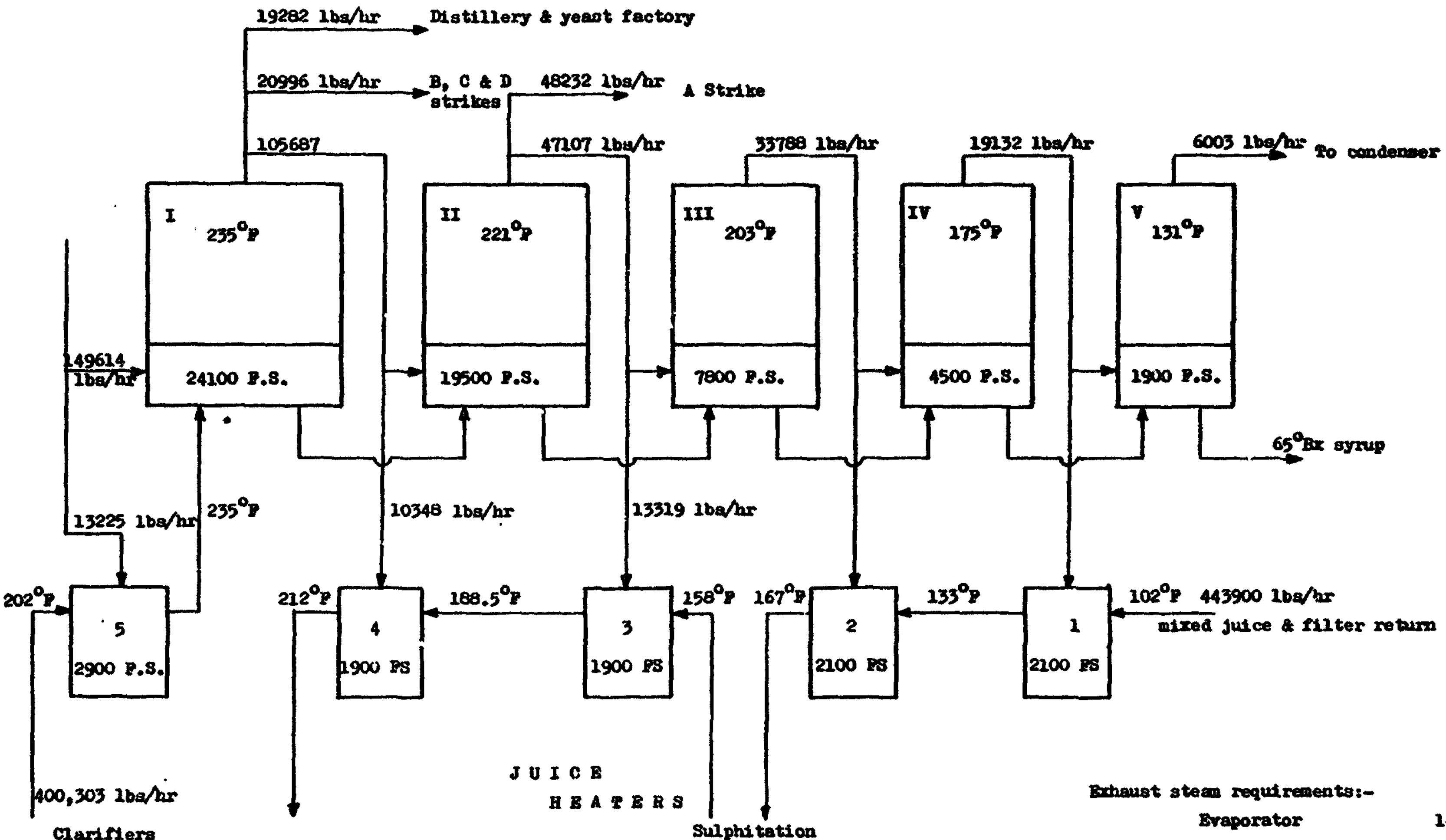


Exhaust steam requirements:-

Evaporator	34890 lbs/hr
Clarified juice heater	9026 "
Total	43916 lbs/hr

Fig. A2.3 EVAPORATOR AND JUICE HEATERS ARRANGEMENT - SHOA

QUINTUPLE EFFECT EVAPORATOR



Exhaust steam requirements:-

Evaporator	149614	lbs/hr
Clarified juice heater	13225	lbs/hr
Sugar drying	2058	"
Total :	164897	"

These improvements would result in the P.R.V. reaching a near closed position under normal or average conditions (as shown in Table 5). It would then not be possible to operate the B.P. generator in the present mode i.e., disconnected from the grid system. This means that at times when a vacuum pan is struck, stands idle, or is cut-over, the flow of exhaust steam from the prime movers, which cannot be altered for reasons mentioned in the foregoing, may be in excess of process demand thereby resulting in blowing-off to atmosphere, a situation that is not conducive to the generation of surplus bagasse.

However, if the B.P. generator's alternator is tied to the national grid, the steam flow through the former could be reduced to match the process demand during such an occurrence. In turn, the boiler output would be proportionally reduced thereby resulting in the generation of excess bagasse. Moreover, if the electrical energy then generated proved to be insufficient for the internal needs of the factory, the shortfall would be instantly compensated by the national grid. Conversely, during occurrences when process demand is higher than average (e.g., starting and seeding of pans), the output of the generator may then be in excess of the internal electrical energy need of the factory. This excess would then flow into the national grid.

Table 5: STEAM AND ELECTRICAL FLOWS IN IMPROVED FACTORIES

	Metahara		Wonji		Shoa	
	kg/hr	%	kg/hr	%	kg/hr	%
Steam						
Mill Drives	22,109	23.5	5,323	21.8	18,488	25.3
Boiler Aux.	-	-	289	1.2	2,045	2.8
B.P. Generator	44,515*	47.2	17,683	72.3	41,572	56.9
P.R.V.	23,771*	25.2	-	-	7,577	10.4
Total Process	90,395	95.9	23,295	95.3	69,682	95.4
Other Uses	3,871	4.1	1,151	4.7	3,350	4.6
Boiler Output	94,266	-	24,[illegible]46	-	73,032	-
		kWh		kWh		kWh
Electrical						
Generation	4,200		1,204		3,558	
Internal Use	3,900		1,103		3,257	
New Process Use	300		300		300	
Excess (Deficit)	-		(199)		1	

Note: For Metahara the flow through the P.R.V. and BP generator is adjusted for balanced electrical energy generation and use. If use is made of full generator capacity, hourly exportable energy would be 1800 kWh with flow through the PRV being reduced to 4,692 kg/hr or 5% of boiler output.

Therefore, if the value of surplus bagasse proves to be higher than the price of electrical energy purchased from the grid, the balancing effect previously provided by the P.R.V. could now be provided by the B.P. generator when the alternator of the latter is tied to the grid.

Hence, when equipped with back pressure governors, B.P. generators will maintain their exhaust pressure (back pressure) at a pre-determined level by modulating the steam admission to the turbine, thus ensuring that the amount of process steam is in balance with the steam requirements of the boiling house. It must be emphasized that the condition can only take place when the B.P. generator is synchronized with the grid system.

Unfortunately, the factories are currently started (warmed-up) by drawing power from the grid but, once the B.P. generators are placed on line, the factory electrical bus is disconnected from the grid. The reason for doing this is to avoid what has been tentatively ascertained to be operational problems associated mostly with the characteristics of internally generated power. One of the characteristics of the internally generated electrical energy is the abnormally low power factor.

Furthermore, a review of the one-line diagram provided by EELPA for the interconnecting facilities between the factory and the grid system indicates inadequate protective devices for the preservation of the integrity of the grid system.

Once these operational problems are dealt with to the satisfaction of EELPA and adequate protective devices are in place, there should be no objection to maintaining the coupling of the factory bus to the grid even when the factories are operating. This mode of operation would provide maximum benefits from the implementation of the mission recommendations pertaining to improvements in process heating requirements.

Improving Electrical Power Factors

As noted, the power factors were disturbingly low at the three factories. The following readings were made during the site visits:

		Metahara	Wonji	Shoa
MW	(meter)	1.9	1.2	1.2
KVA	(meter)	2.95	2.5	2.6
Power Factor	(meter)	0.65	0.65	0.75
Power Factor	(calculated)	0.64	0.48	0.46

These low power factors may explain why the factory systems are disconnected from the grid when the plants are operating. Should they remain tied to the grid, EELPA would have to generate and supply reactive power. But, as pointed out in the foregoing, in order to maximize the production of surplus bagasse, the two systems should preferably remain tied at all times.

Moreover, the added processes contemplated by the mission to further improve the production of surplus bagasse require electrical energy beyond the present level of generation. If that additional energy can be obtained without increasing the steam flow, the excess bagasse produced by the added processes and other improvements would remain intact.

Therefore, as the alternator which generates electricity for the factory is limited by the current which flows through it, and as the useful power provided is proportional to the product of the flow in g current and the power factor, the alternator, with a power factor of 0.4 will only be able to produce half the power it could with a power factor of 0.8.

It follows from the foregoing that the alternator KVA must be adapted to the power factor as given by the consumers to ensure that it can generate the active power corresponding to the turbine power and at the same time supply the reactive power required. It is, of course, possible to load the alternator with a greater active power if the reactive power is generated by another source, such as EELPA.

Unfortunately, this alternative is not practical when the integrity and efficiency of the grid system is considered, since the following adverse effects will result from the factories' low power factors:

-- an increase in the losses through the Joule effect in the lines; these losses are proportional to the square of the flowing current.

-- an increase voltage drop in EELPA's alternators and lines, and

-- a decrease in the efficiency of EELPA's alternators.

Furthermore, assuming that this alternative is feasible, the new tariff structure proposed by EELPA may prove to be a financial burden to the factories. This proposed tariff contains a special power factor clause. The clause would offer a rebate to consumers with improved power factors as well as penalties for those having low power factors. The base level of power factor envisaged by EELPA is 0.85. Therefore, the only alternative for the existing generating plants at the factories is to install capacitors to generate the reactive power needed to improve the power factor of the factory systems and to reduce the power (KVA) which the alternators must supply to the existing factory consumers, thereby leaving an excess available for add-on processes. Various simulations with the add-on processes indicate that the P.R.V.s' reach near closed position and that a small shortfall of electrical energy has to be imported to sustain the operation at the present level of power factor. With an improved power factor, the factories (even with the add-on processes) would be self-sufficient in electrical energy.

Unburnt Particles of Bagasse in Flue Gases

Table 2.4 summarizes the combined effects of steam utilization improvements and drying based solely on heat gains. There is, however, another aspect which has to be taken into account. In para. 2.23 mention was made of the scrubbing effect that takes place in a dryer resulting in the capture of most unburnt particles entrained in the flow of flue gases.

The simulations, based on data supplied by ESC, show that the sum of boiler losses expressed in terms of bone dry bagasse, due to entrainment of unburnt particles in flue gases, radiation losses, boiler blowdown and other undetermined losses amount to 16,739; 3,589; and 5,392 tonnes respectively for Metahara, Wonji and Shoa (refer to Table 6 under classification 'other losses'). Based on data accumulated in Hawaiian and Mauritian sugar factories it is estimated that 65% of these losses are recoverable in the form of unburnt particles. Hence the estimated amounts, on a bone dry basis, of recoverable unburnt particles are:

Table 6: UNBURNT PARTICLES RECOVERED BY DRYING

	Metahara	Wonji	Shoa	Expanded Shoa
Tonnes Bone Dry Basis	10,880	2,333	3,505	9,133

It is necessary to differentiate between the 'wet' and 'dried' forms of the surplus bagasse because there are two possibilities regarding the drying process:

Table 7 EXCESS BAGASSE IN LOOSE WET FORM
(In Tonnes, bone dry basis)

	Metahara	Wonji	Shoa	Expanded Shoa
Due drying & steam utilization improvements	35,145	21,419	16,705	43,530
Due to capture of unburnt particles in the dryer	10,880	2,333	3,505	9,133
Total	46,025	23,752	20,210	52,663

Table 8: NET EXCESS BAGASSE IN LOOSE WET FORM
(In Tonnes, bone dry basis)

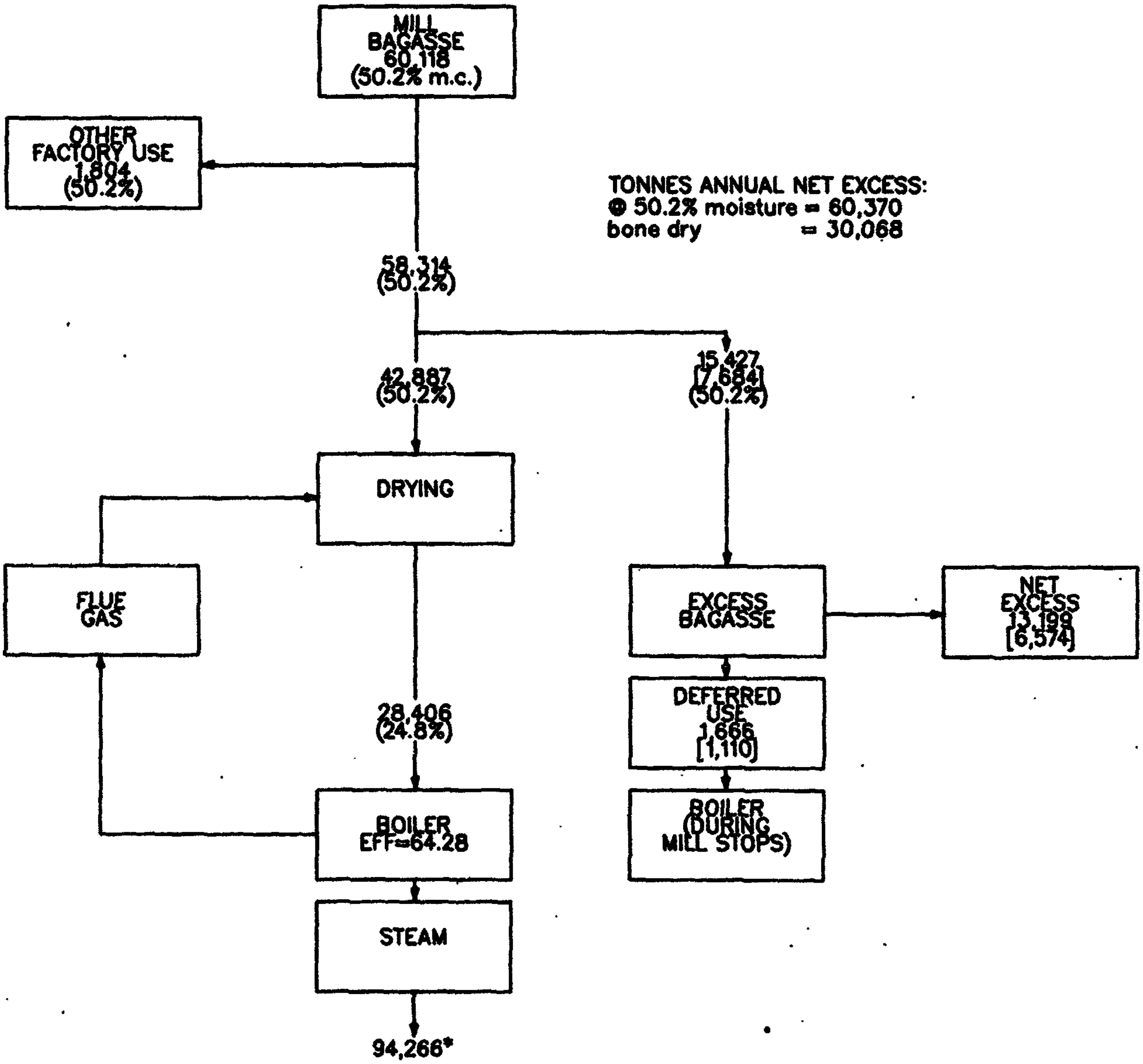
	Metahara	Wonji	Shoa	Expanded Shoa
Due to drying & steam utilization improvements	30,068	20,792	11,390	36,103
Due to capture of unburnt particles in the dryer	10,880	2,333	3,505	9,133
Total	40,948	23,125	19,895	45,236

(1) Use all available waste heat to dry only the amount of bagasse needed for steam generation. In this case, the excess bagasse will be in a 'loose wet form' (refer to Figs. A2.4, A2.5 and A2.6). This would be the ideal method if the excess bagasse is needed for pulping; since in this case the boiler efficiency will be at its maximum and consequently less fiber will be burnt, thus ensuring a maximum excess. For the purpose of pulping there is no necessity to dry the excess bagasse.

(2) Use all available waste heat to dry bagasse to a pre-defined moisture content, i.e. 12% for densification purposes: Typically, the amount of heat available will normally dry more bagasse than the excess to be densified; this surplus is then returned to that part of the mill bagasse stream that was not fed to the dryer. This mixed stream will be at a higher moisture level than that delivered to the boiler in the previous case. This will have the disadvantage of proportionally lowering the boiler efficiency resulting in a lesser amount of excess (bone dry basis) than in the previous case. This excess is defined in the foregoing as 'Loose Dried Form' (refer to Figs. A2.7, A2.8 and A2.9).

Figure A2.4

METAHARA
WET BAGASSE FLOW WITH DRYING

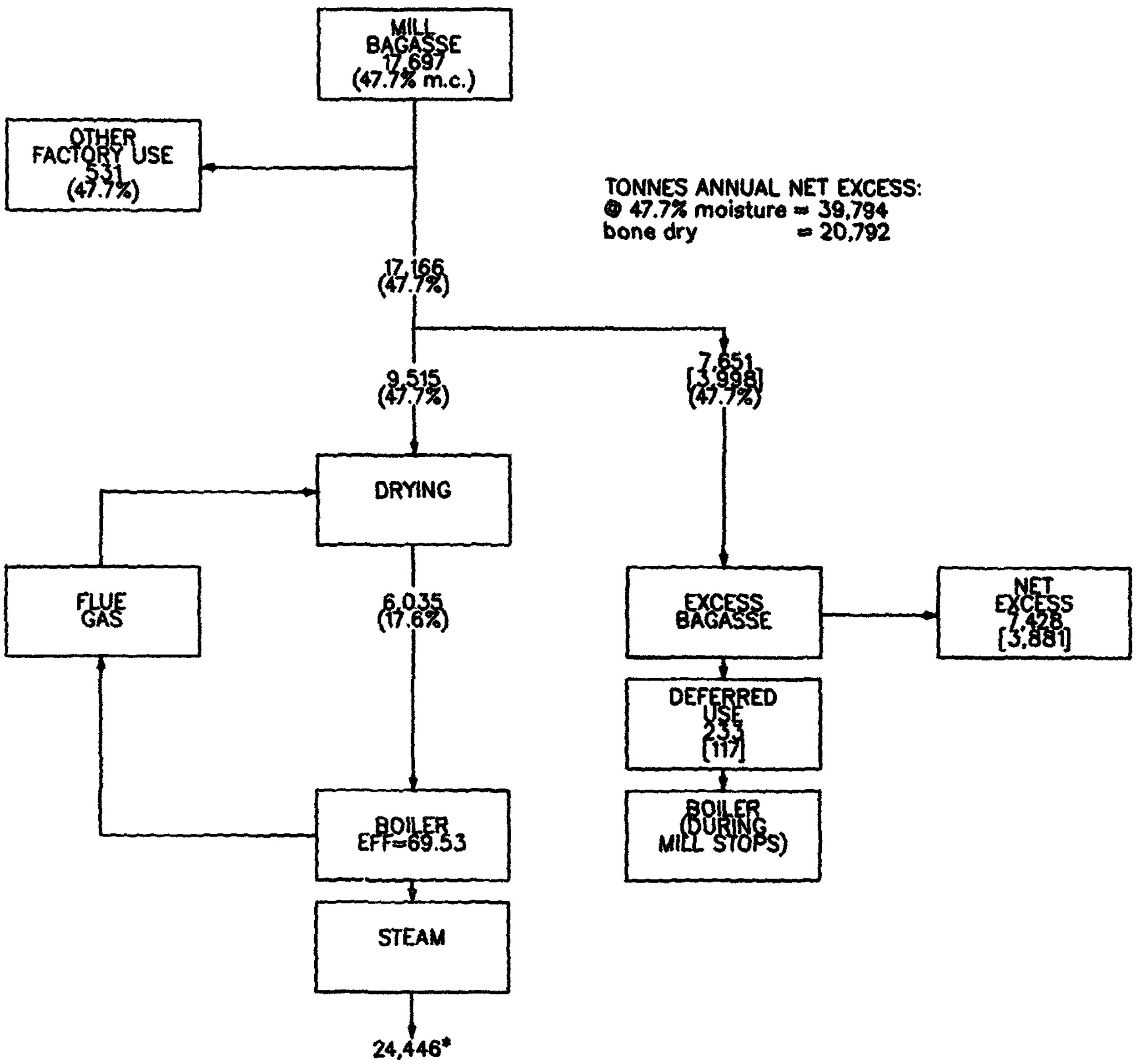


Note : Open figure is bagasse flow, wet basis, in kgs/hour
Figure in [ ] is bagasse flow, bone dry, in kgs/hour
Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

WORLD BANK-30383F

Figure A2.5

WONJI
WET MILL BAGASSE FLOW WITH DRYING

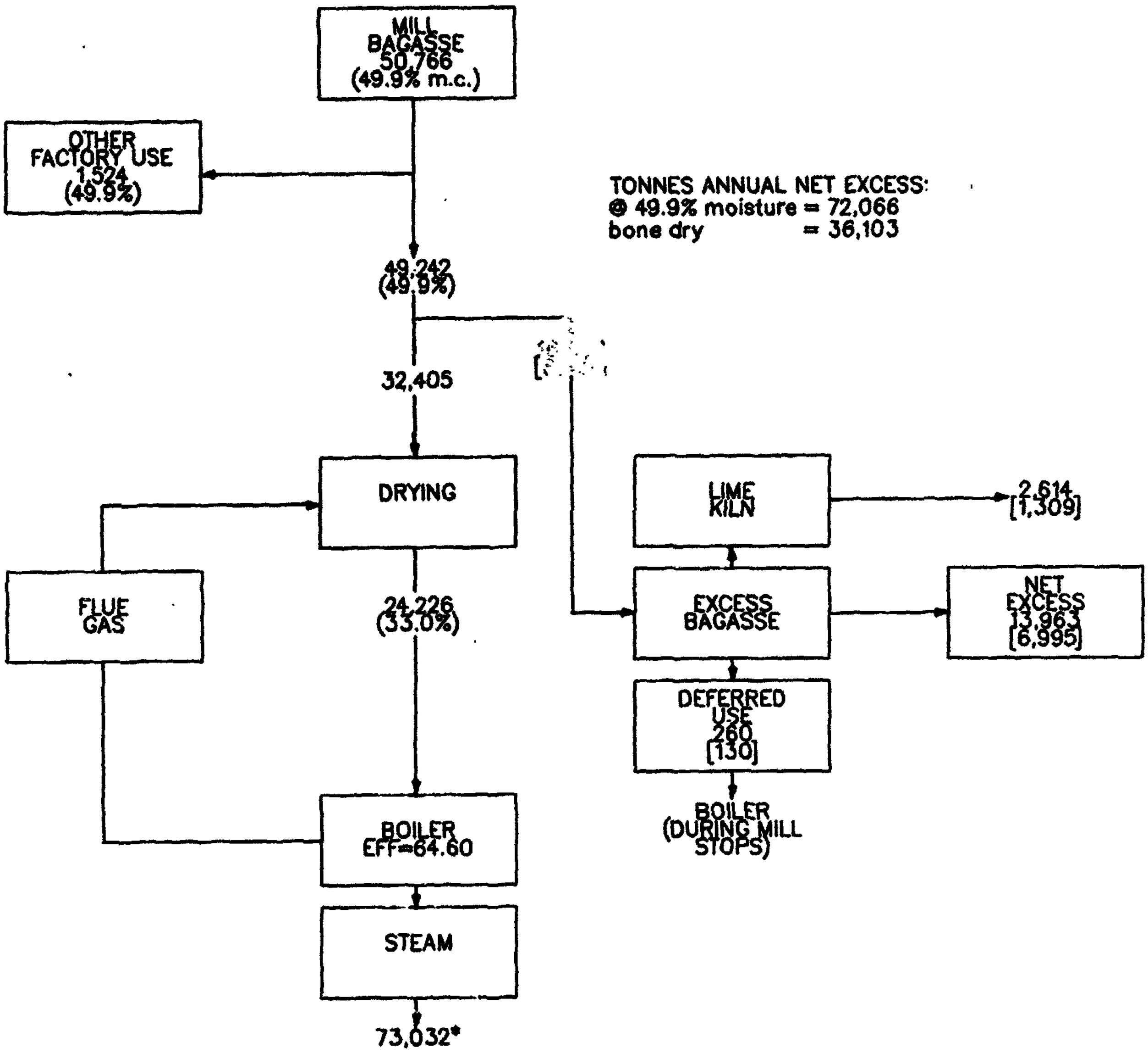


Note · Open figure is bagasse flow, wet basis, in kgs/hour
· Figure in [ ] is bagasse flow, bone dry, in kgs/hour
· Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

WORLD BANK-30383K

Figure A2.6

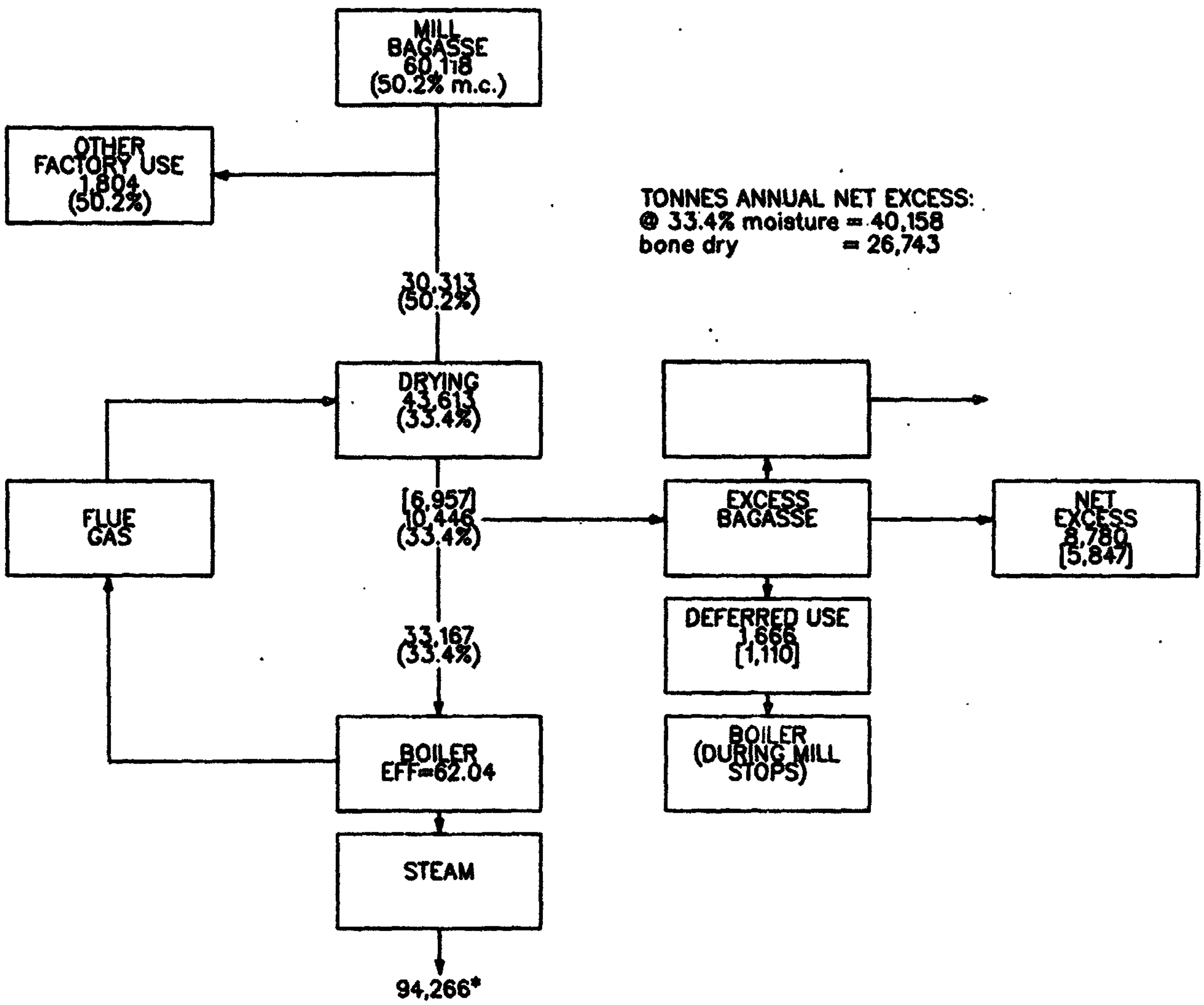
SHOA
WET MILL BAGASSE FLOW WITH DRYING



Note : Open figure is bagasse flow, wet basis, in kgs/hour
· Figure in [ ] is bagasse flow, bone dry, in kgs/hour
· Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

Figure A2.7

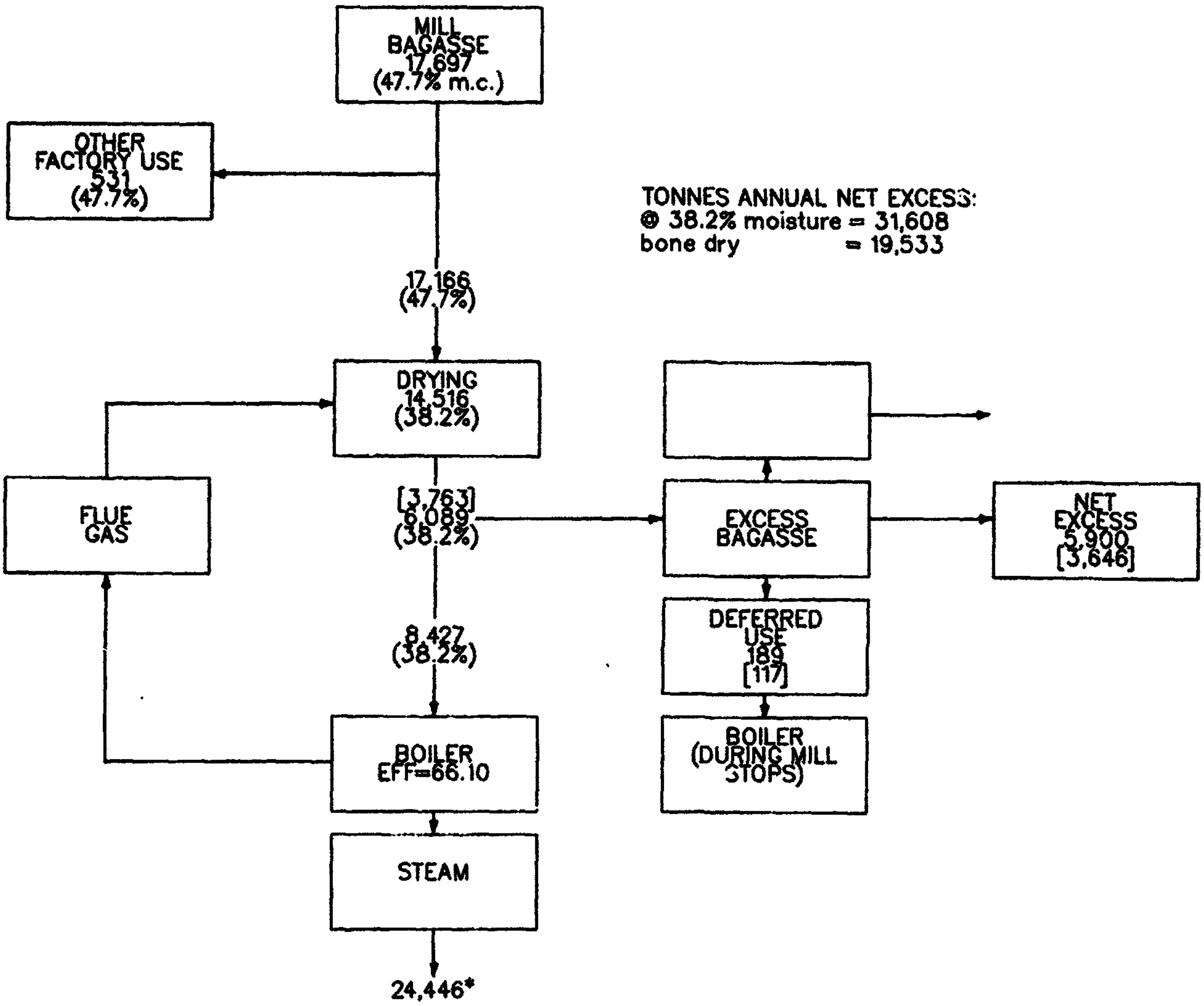
METAHARA
DRIED BAGASSE FLOW



Note · Open figure is bagasse flow, wet basis, in kgs/hour
· Figure in [ ] is bagasse flow, bone dry, in kgs/hour
· Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

Figure A2.8

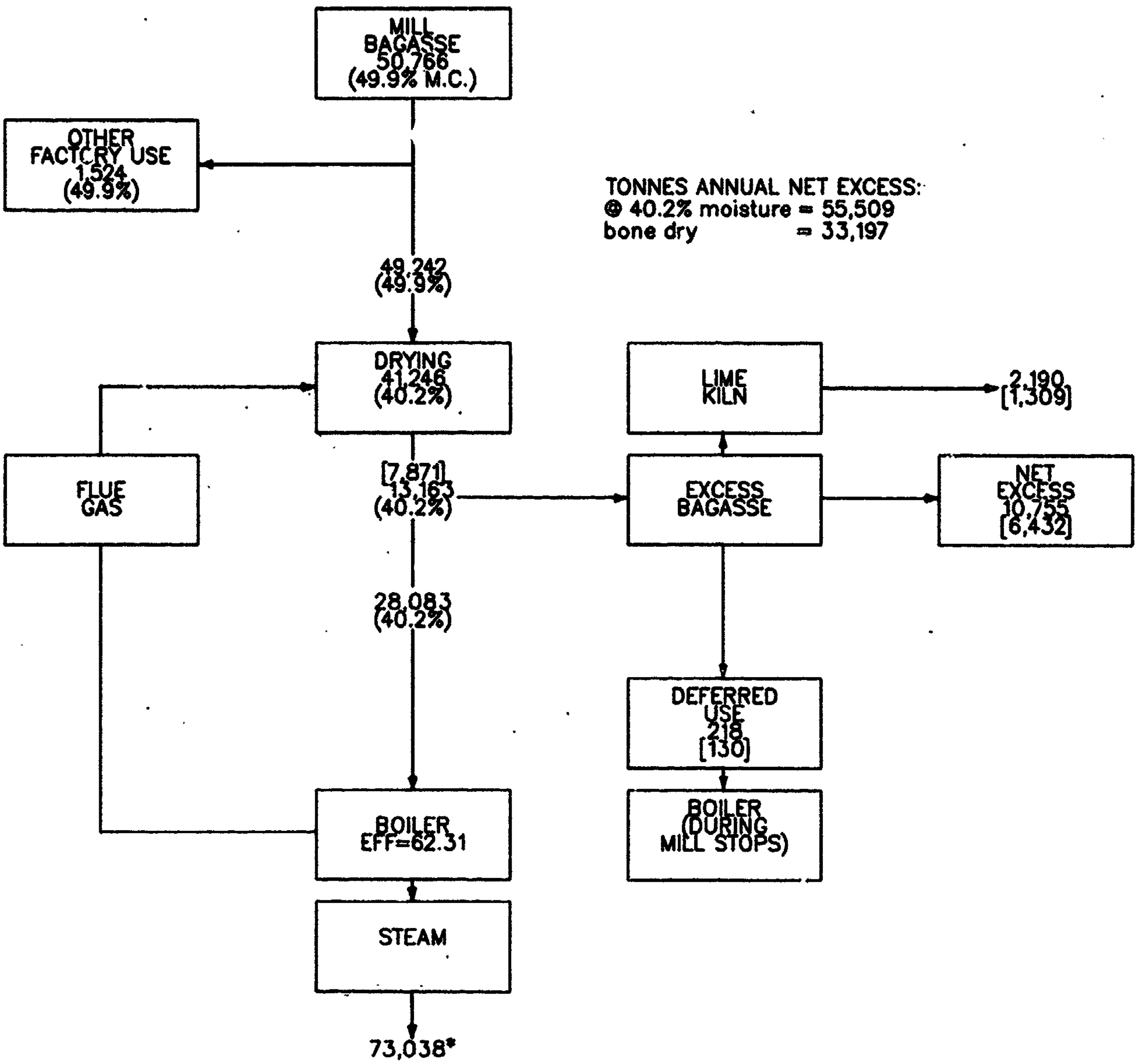
WONJI
DRIED BAGASSE FLOW



Note · Open figure is bagasse flow, wet basis, in kgs/hour
· Figure in [ ] is bagasse flow, bone dry, in kgs/hour
· Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

Figure A2.9

SHOA
DRIED BAGASSE FLOW



Note : Open figure is bagasse flow, wet basis, in kgs/hour
: Figure in [ ] is bagasse flow, bone dry, in kgs/hour
: Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

THE FINCHAA PROJECT

Project Description

The Finchaa Sugar Project consists of the complete and integrated development of a 13,000 hectare sugar estate with a factory, ethanol plant and all associated irrigation, housing and infrastructure.

The factory will be designed in the initial development of the project with a nominal cane throughput of 4000 tonnes/day, to produce 84,000 tonnes/year of plantation white sugar with provisions for future expansion to 6000 tonnes of cane/day and 124,000 tonnes/year of plantation white sugar.

In the initial phase, 6,114 hectares will be harvested to produce 708,000 tonnes of cane per year. The final phase harvest will be 9,171 hectares per year.

The ethanol plant will be designed for the initial development of the project to produce alcohol at a rate of approximately 45,000 liters/day with provisions for future expansion that will permit production of alcohol at a rate of approxim ately 67,500 liters/day.

Project Location

The project will be constructed on the west bank of the Finchaa River in the Finchaa Valley which is located within the Wollega Administrative Region of Ethiopia. Access to the project area from Addis Ababa is provided by all-weather road, 285 km long, to Finchaa Village which is located on the highlands near the Finchaa Power Dam and at approximately 40 km from the boundary of the site.

Review of Tender Document

This mission has reviewed the tender document (Contract No. FP3, April 1982), prepared by Tate & Lyle Technical Services Limited (TLTS), for the design, supply, construction and commissioning of a sugar factory and ethanol plant for the initial phase of the Finchaa Project. The mission's comments pertaining to the above mentioned tender document are presented herewith.

Design

The projected factory is of "classical" design using (i) a milling process for extracting cane juice, (ii) a sulphitation process for the decolorization of the juice and syrup, and (iii) a crystallization process which utilises a three boiling system consisting of the double curing of 'A' massecuite for the production of commercial mill white sugar, 'B' magma as footing for 'A' massecuite and blending of remelted single-cured 'C' sugar with syrup; this blend is to be used for 'A' massecuite and as footing for 'B' and 'C' massecuites.

In this design conventional boilers, with air-preheaters, provide the live steam requirement at 2,200 KPa/376 Deg. C., and conventional Back Pressure turbo-generators (BPTG) expand a portion of the live steam to an exhaust steam pressure level of 125 KPA while generating electrical energy to satisfy the factory requirement.

The high voltage substation, inclusive of incoming feeder, step-down transformer and outgoing feeder for the EELPA supply is adequately sized (4,000 KVA) and protected, thereby allowing the factory to operate with its BPTG synchronized with the national grid. In addition adequate power factor correction capacitors are called for in the tender. Their installation would create an environment which is conducive to optimal steam utilization, and electrical energy generation and utilization.

Impact of Steam and Electrical Energy Use on Excess Bagasse Generation

The evaporator station, vapor cell and quadruple effects provide all the steam necessary for juice heating and vacuum pan boiling, except for clarified juice pre-heating which uses exhaust steam. The ethanol plant uses exhaust steam for its heat requirement. The resulting steam consumption of the factory has been established by TLTS to be 456.4 kg/TC without the alcohol plant and 479.6 kg/TC with the alcohol plant. These levels of steam consumption were computed during a visit on January 30, 1985, to TLTS and are significantly lower than the rates previously computed by TLTS (Phase II Studies, Volume III of April 1982) i.e., 548.9 and 594.8 kg/tch respectively for the factory without and with the alcohol plant.

However, in this recent computation the amount of live steam reduced to the pressure level of the process steam is still rather high at 13.32 t/hr in the case of a factory with distillery (15.05 t/hr without a distillery); this flow could be rerouted through the BPTG if adequate instrumentation is provided for steam flow distribution and BPTG controls as pointed out in Annex 2.

Thus, with the factory BPTG synchronized with the public grid, improved steam utilization would result and in turn larger surpluses of bagasse would be generated. Moreover, the factory would produce more electrical energy from the same steam flow and this additional energy could then be utilized for other uses, such as the load requirements of add-on processes, namely the ethanol plant, drying and densification.

The internal factory electrical energy requirement, computed by TLTS, appears to be extremely high at 20.0945 kWh/tc in comparison to the present consumption of the existing factories which range from 17.85 to 18.77 kWh/tc since the effect of the integrated ethanol plant requirement should be negligible i.e., 0.074 kWh/litre or 0.7423 kWh/tc. TLTS has computed the ethanol plant requirement to be 0.2787 kWh/litre or 2.55 kWh/tc. The principal parameters assumed or calculated, by TLTS in the design for the factory are:

Parameters	Units	Quantity
Optimum Harvesting Period (October - May)	days	214
Harvesting Time Lost Due To Rain	days	11
Harvesting Opportunity Time	days	203
Factory Non-Operating Time	days	26
Planned Shut Downs During Crop	days	6
Time Lost Other Than Planned	days	20
Effective Factory Operating Time	days	177
Cane per Day	tonnes	4,000
Cane per Hour	tonnes	183
Cane per Crop	tonnes	708,000
Steam:		
Process Use	kg/tch	390.51
Other Use	kg/tch	65.86
Total	kg/tch	456.37
Electrical Energy:		
Generation	Kwh/tc	20.09
Factory Internal Use	Kwh/tc	20.09
Ethanol Plant:		
Effective Operating Time	days	199 *
Continuous Operating Hours/Day	hours	24

Note: * The ethanol plant will still operate when the factory, due to mechanical failures, is not grinding cane.

In addition to the above mentioned parameters, this mission assumed the following parameters to simulate the material, thermal and electrical energy balances of the factory, as presently designed by TLTS for the purpose of determining the bagasse energy lost and the excess bagasse generated (refer to Figs. A3.1-A3.2).

Parameters	Units	Quantity
Factory Mechanical Time Efficiency	%	91.07
Fiber in Cane	%	13.50
Bagasse in Cane	%	28.50
Moisture in Bagasse	%	50.00
Alcohol Plant:		
- Steam	kg/litre	4.00
- Electrical Energy	KWh/litre	0.074

Furthermore, the mill bagasse hourly flow was discounted by 3 % for 'other factory usage' in addition to the amount retained for 'deferred usage'(566 kg/hr required to maintain the boiler at 15% of MCR when the milling section of the plant experiences intermittent break-downs).

If the factory, without the ethanol plant, is operated as presently designed the following is observed:

(1) 3,489 KWh would be generated hourly and the plant would utilize 3,428 KWh leaving a surplus of 61 KWh for other use, such as domestic load, etc.

(2) Boiler losses in terms of 'bone dry' bagasse in
- Flue gasses = 50,860 tonnes/year
- Other = 5,760 tonnes/year

(3) Excess Bagasse Generated (bone dry basis) = 22,470 tonnes/year

This excess is in a loose wet form (50% m.c) which is expensive and unsafe to store.

With the ethanol plant in operation, the additional steam requirement of 7342 kg/hr would generate 602 kWh of which 136 kWh would be used by the distillery; an hourly balance of 527 kWh would then be available for other use. The excess bagasse generated, on a dry basis, would then be 14,755 tonnes/year when accounting for the supply of steam to the alcohol plant for 199 days i.e., 22 days more than the 177 of effective cane grinding.

Mission's Recommendations

The mission recommends that some of the specific components of the Project identified in Chapter 4 also be adopted for the Finchaa factory, such as:

(1) Bagasse Drying and Densification System

(2) Bagasse Reclaim System

The effect of these systems, during the initial phase of the Finchaa project (4,000 tonnes cane/day), on the generation of net excess bagasse, in a densified form, is shown in the following table and in Figs. A3.3-A3.4. Moreover, the mission assumes that the internal factory electrical energy requirement may be reduced from 20.0945 kWh/tc to 18.734 kWh/tc (19.4763 kWh/tc inclusive of ethanol plant) and that 'other' steam use may also be reduced, from 65.855 kg/tch to 18.63 kg/tc, by rerouting a larger percentage of live steam through the BPTG instead of routing through the PRV station. In this assessment the recent TLTS's computation of steam requirement was assumed i.e., 456.4 kg/tc and 479.6 kg/tch respectively for the factory without and with the ethanol plant.

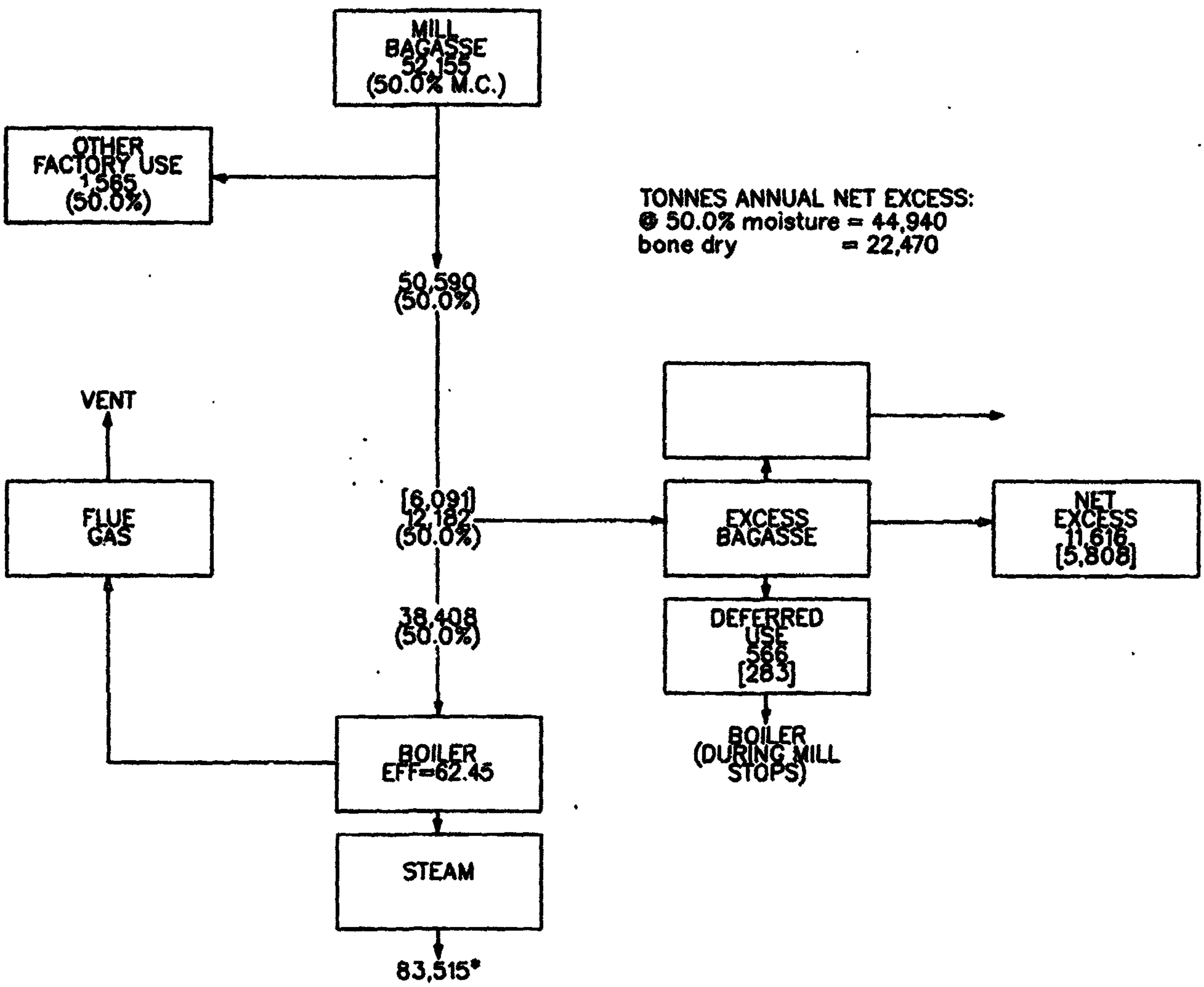
NET EXCESS BAGASSE
(Tonnes Bone Dry)

	Without Ethanol Plant	With Ethanol Plant
- Due to Drying	27,074	22,161
- Due to capture of unburnt particles in the dryer	1,872	2,453
- Sub-Total	28,946	24,614
- Less Amount used by Ethanol plant when factory is not grinding cane i.e., 22 days	-	735
- Total Net Excess	28,946	23,879

It should be emphasized that the recommended modifications would yield, on a bone dry basis, a net excess in densified form of 23,879 tonnes (combustion efficiency of 74.5 %) versus 14,755 tonnes in the form of wet loose bagasse (combustion efficiency 62.45 %) with the present design, when accounting for the ethanol plant requirement.

Figure A3.1

FINCHAA
WET MILL BAGASSE FLOW

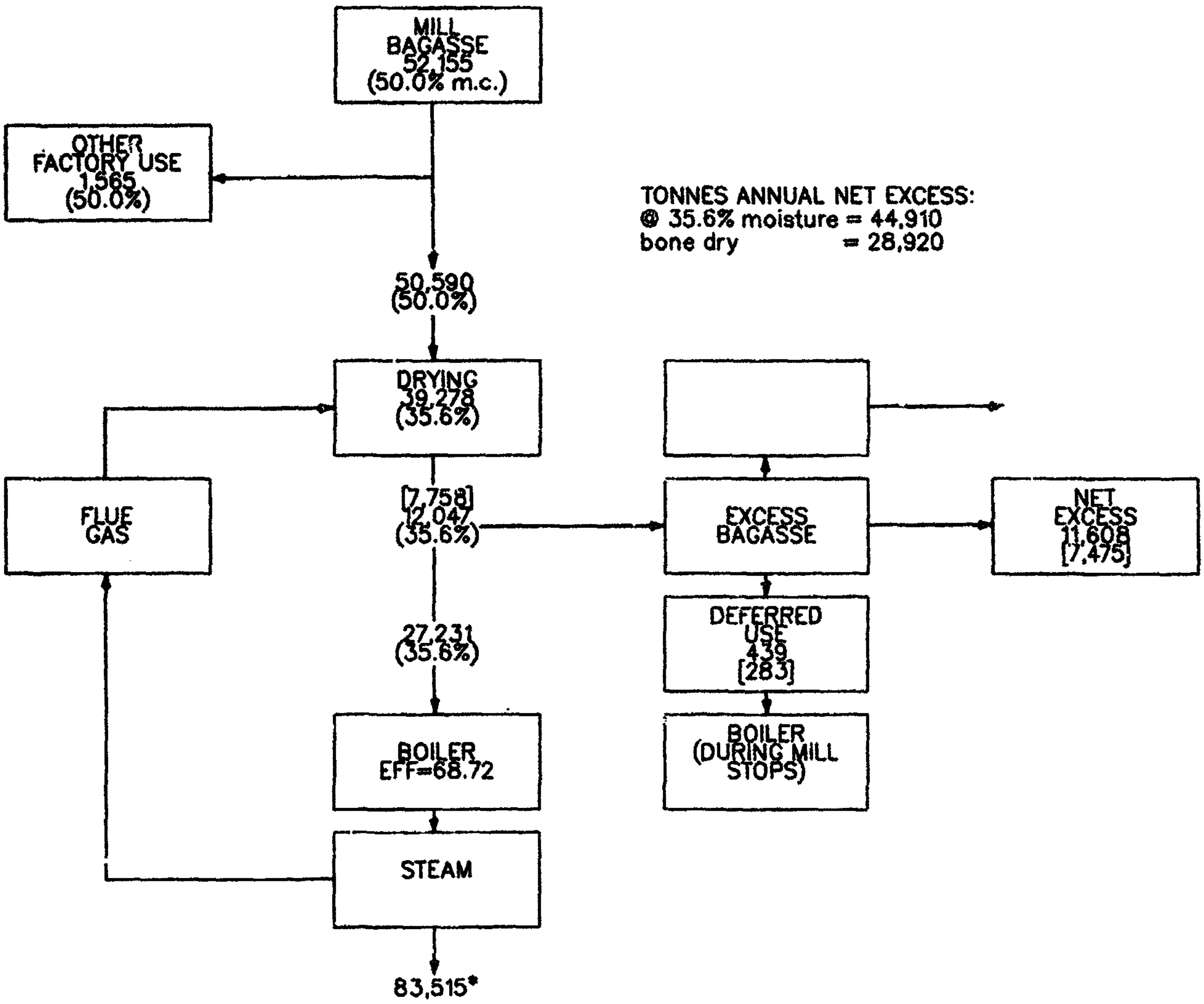


Note : Open figure is bagasse flow, wet basis, in kgs/hour
· Figure in [ ] is bagasse flow, bone dry, in kgs/hour
· Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

WORLD BANK 303838

Figure A3.2

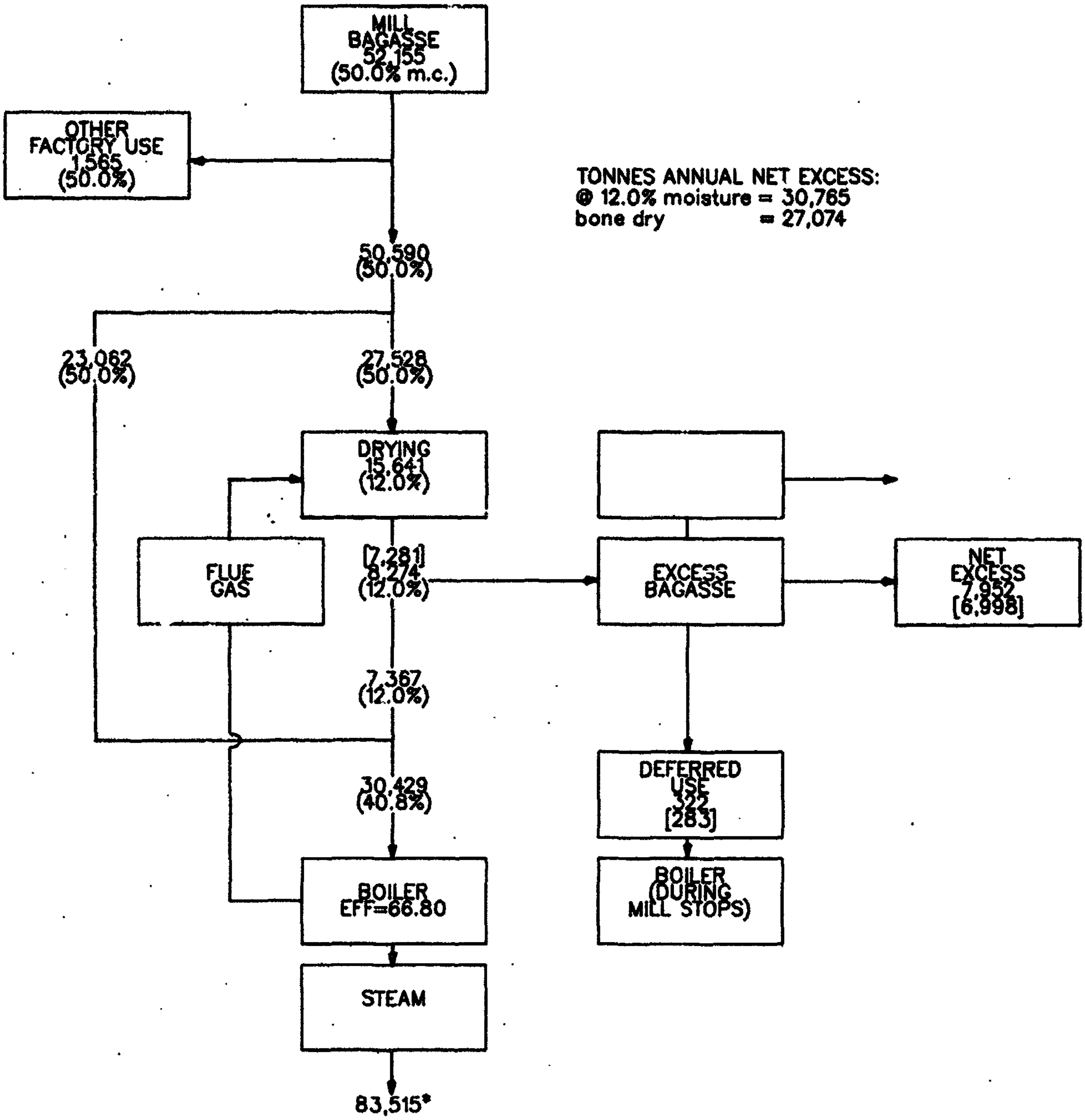
FINCHAA
DRIED BAGASSE FLOW



Note · Open figure is bagasse flow, wet basis, in kgs/hour
· Figure in [ ] is bagasse flow, bone dry, in kgs/hour
· Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

Figure A3.3

FINCHAA
DENSIFIED BAGASSE FLOW

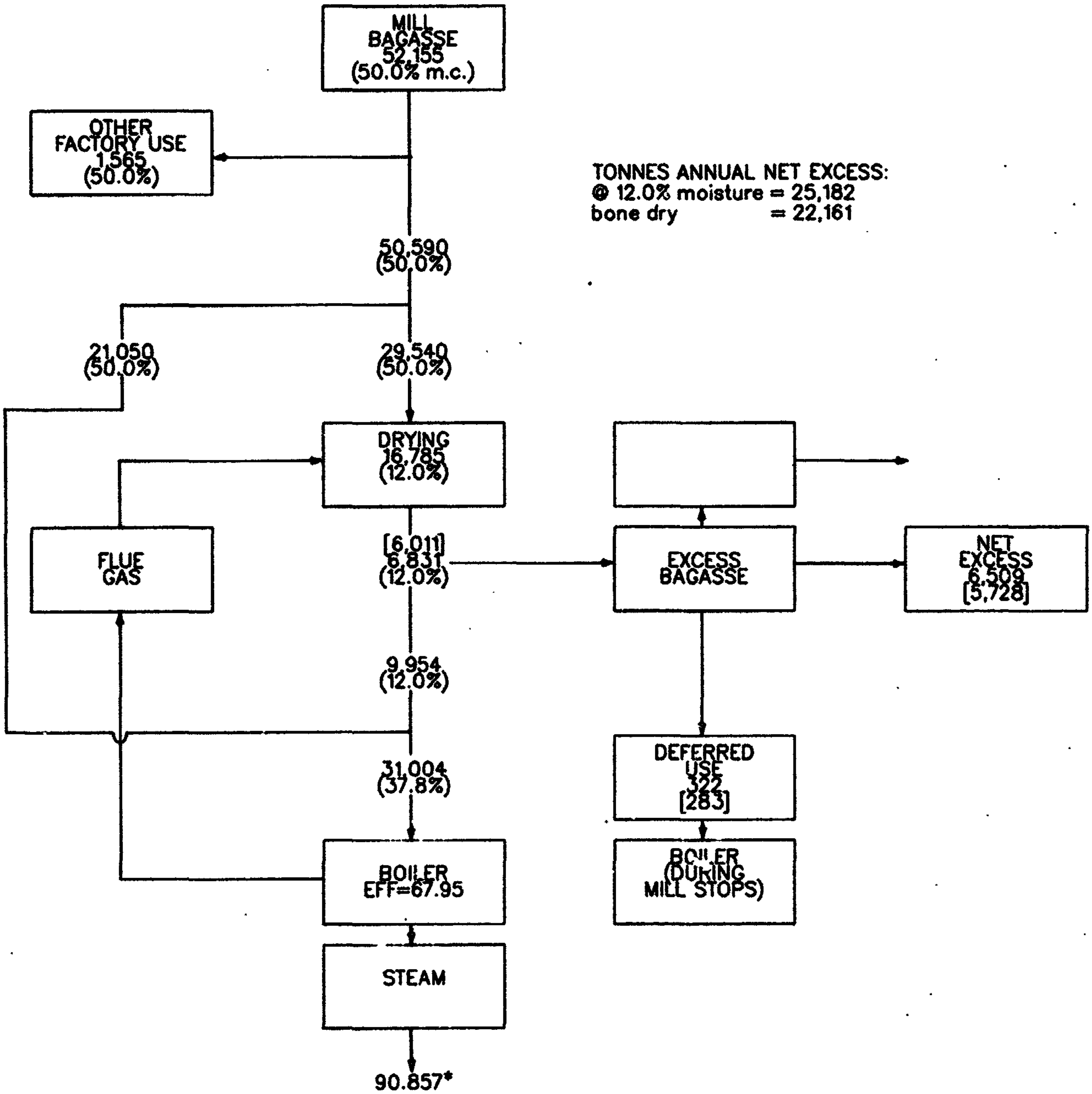


Note : Open figure is bagasse flow, wet basis, in kgs/hour
: Figure in [ ] is bagasse flow, bone dry, in kgs/hour
: Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

WORLD BANK-30383H

Figure A3.4

FINCHAA
DENSIFIED BAGASSE FLOW WITH ALCO. PLANT



Note · Open figure is bagasse flow, wet basis, in kgs/hour
· Figure in [ ] is bagasse flow, bone dry, in kgs/hour
· Figure in ( ) is bagasse moisture in percentage
* is steam flow in kgs/hour

WORLD BANK-30383G

Moreover, it is recommended that the boiler be retrofitted with a combination dust/oil burner if briquettes are to be burnt; oil burning is essential in preventing flame-outs and the ratio of oil to bagasse dust is expected to be 20:80. In addition a briquette grinder must also be provided to reduce the briquette to dust particle of less than 3 mesh prior to being fed to the dual fuel burner. But, if pellets are to be burnt instead briquettes, then none of the above mentioned equipment would be required if the boiler was already fitted with travelling grates.

The live steam pressure of 2,200 KPA is on the low side for a modern factory and will limit the potential of electrical generation. This may not be important for the present, given the ample supply of comparatively low-cost electrical energy obtained from the hydro projects. The use of simpler and less expensive BPTG's instead of condensing-extraction units can be justified for the same reason.

On the other hand, now is the opportunity to plan for higher steam pressures and it is recommended that the choice of the boiler pressure be reconsidered. The difference in cost between a 2,200 KPA boiler and a 4,205 KPA/425 Deg. C. boiler may prove to be economically justifiable and, if that is the case, it might be worth while to install a 4,205 KPA boiler even if it has to operate at 2,200 KPA initially. This would provide a potential for future expanded generation of electrical energy for export to the grid when peak demands for energy and capacity by EELPA arise in the future and/or for other uses such as irrigation.

With the higher pressure boiler and an extracting turbo-generator extracting at 2,200 KPA the hourly excess electrical energy would be 4,700 kWh during the effective operating hours of the cane grinding season, i.e., 18.2 GWh annually.

However, if an extracting-condensing turbo-generator is instead selected and if the net excess of densified bagasse is burnt during the 199 days when the ethanol plant is operating, then an additional hourly excess electrical energy of 5,000 kWh would be available; thus, the total hourly excess would be 9,700 kWh during 21.86 hours of the 177 days of effective cane grinding and 5,000 kWh hourly during the balance of 2.14 hours of the same period and during the other 22 non-grinding days i.e., an annual excess of 42 GWh. This energy could then be utilized for irrigation since the non-grinding season correspond to the rainy season.

Moreover, so as to ensure optimal bagasse energy utilization, the mission recommends that the following performance guarantees be included in the tender documents (contract no. FD3, April 1982):

(1) Factory steam consumption at 4305 KPA/425 degrees C. to be less than 457 kg. per tonne cane per hour;

(2) Factory energy consumption to be less than 18.75 kWh/tonne cane per hour;

(3) Factory mechanical time efficiency to be more than 91%;

(4) Alcohol plant steam consumption at 4,205 KPA/425 degrees C. to be less than 4 kg. per liter;

(5) Alcohol plant electrical energy consumption to be less than 0.0745 kWh per liter; and

(6) Electrical energy to be generated at a power factor of more than 0.8

Summary of Net Excess of Densified Bagasse

If electrical energy generation is not the objective then the total excess bagasse available during the first phase of the Finchaa project, on a bone dry basis, would be 58,960 tonnes annually when accounting for the ethanol plant requirement and the use of cane tops, as defined in para. 2.25.

TECHNICAL AND COST PARAMETERS FOR DRYING AND DENSIFICATION SYSTEMS

Drying and Densification System

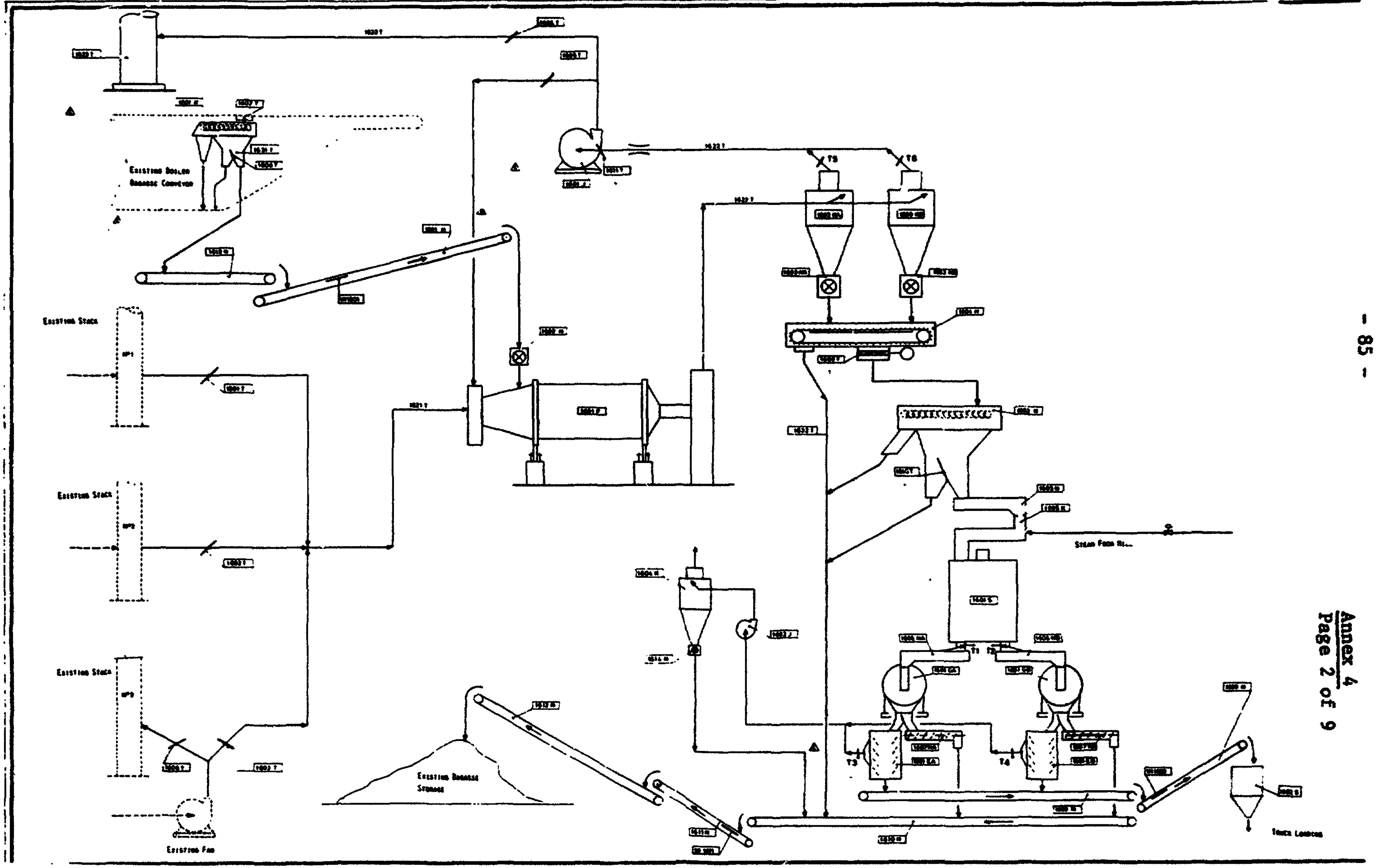
The 'Drying and Densification System' is shown in Fig. A4.1 and its design and operation have been described and discussed in para. 4.19-4.26, as well as in Annex 2. It is noted that this design has evolved from a full-scale industrial system which has successfully proven itself for the past 4 years at the Haina factory of Hamakua Sugar Company Inc., Hawaii. The primary function of the system is to increase the amount of surplus bagasse; this is achieved by using boiler waste flue gases, as a drying medium, to reduce the moisture content of the mill bagasse stream prior to its use as boiler fuel. The lower moisture fuel improves the boiler efficiency which, in turn, results in a fuel savings that translates into the generation of a larger surplus of bagasse. The secondary function of the system is to convert the bagasse surplus into a densified form, but it is imperative that the amount of dried bagasse be greater than the production of densified product such that a portion of the dried bagasse is always being returned as boiler fuel to sustain a higher combustion efficiency.

System Design Considerations

The prerequisite to bagasse densification is the drying of the bagasse to a predefined moisture level of 12-14 % within a tolerance of ±1.5%; the need for preconditioning the dried bagasse prior to densification may at times be necessary and it is achieved by screening and/or heat treatment. The prerequisite to efficient and uniform drying is the particle size distribution of the bagasse feed to the dryer, thus the need for pre-screening the mill bagasse prior to drying. Fortunately, the mill bagasse stream contains more than 60% of particles which are within a range that is conducive to uniform drying and furthermore this acceptable amount is in excess to the amount that could be dried to the predefined moisture level with the available flue gases. Therefore, the size of the particles available for densification is governed by the dryer requirement. If the size of most of the particles exiting the dryer is not suitable for densification then additional screening or grinding of the dried material is required; with the particle size distribution of bagasse which are commonly encountered in the industry, grinding would most likely not be required but if the need for grinding arises then it is more economical to grind the cane prior to milling as this option result in higher sugar extraction.

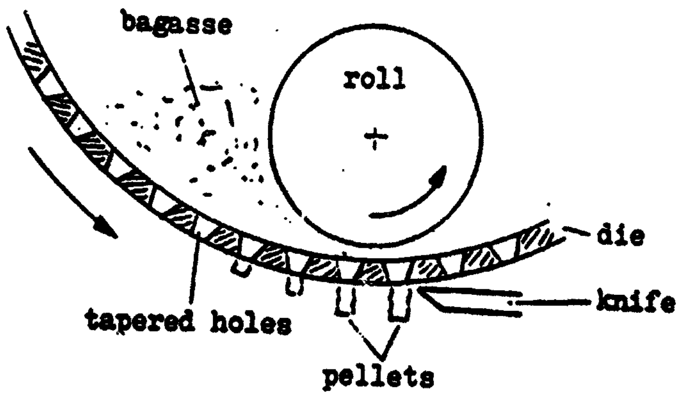
In the proposed system, either one of two methods of densification could be utilised without having any significant impact on the overall system design shown in Fig. A4.1. One of the two methods is by means of a 'briquettor' and the other is by means of a 'pelletizer'. Item 1601GA and/or item 1601GB in Fig. A4.1 could be either a briquettor or a pelletizer.

Figure A4.1: Bagasse Drying and Densification Schematic



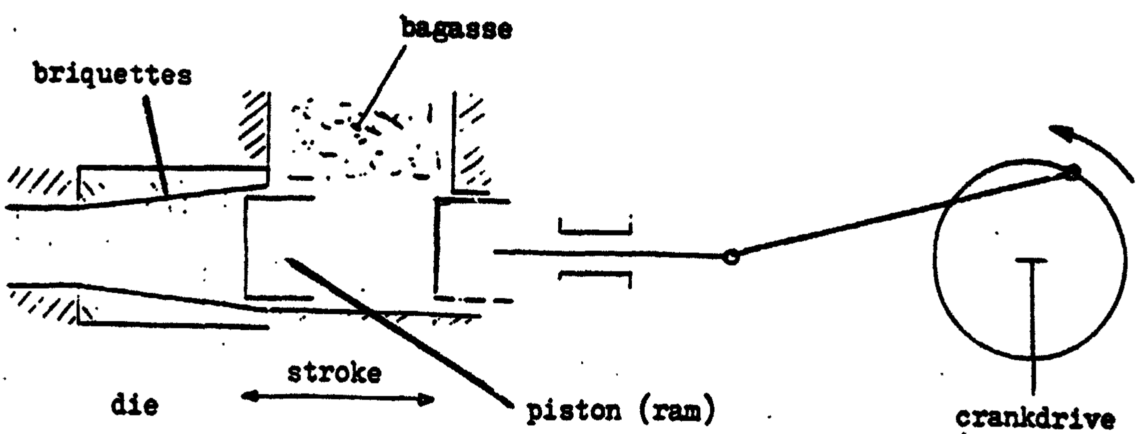
Both machines use similar principles: bagasse is pushed into a conical shaped opening (die). The pressure required to press the bagasse through the die depends on the shape (angle) of the tapered walls and the length of the taper; pressures of up to 1,200 kg/sq. cm. are commonly

Fig. A4.2: PELLETING METHOD



encountered. Pelletizing is a continuous operation since the bagasse is pressed into the die holes by means of rollers (Fig. A4.2). Briquetting is a batch-line operation since the bagasse is hammered into the die by means of a piston (ram) which is energized by a crankdrive (Fig. A4.3). Economic output capacities without excessive wear on dies,

Fig. A4.3: BRIQUETTING METHOD



rollers and rams are only possible when the length of the bagasse fibers are not more than 20% longer than the diameters of the die holes. Fibers which are 20% longer than the die hole diameter require cutting and grinding in the presses thus reducing the capacity and increasing the wear substantially. Bagasse briquettes have diameters ranging from 40 mm to 125 mm and therefore would never require any screening of the dried bagasse prior to densification even when producing the smallest diameter briquette, but pre-screening prior to drying would still be necessary for the reason mentioned in the foregoing i.e., uniform moisture content. The diameters of the pellets range from 6 mm. to 25 mm. It is emphasized that the flowing characteristics of densified bagasse is similar to that of grain, i.e., free flowing, when the diameter is maintained within a range of 6-12 mm.

System Design and Process Description

This description refers to Figure A4.1. The mill bagasse stream is discharged on the existing boiler bagasse conveyor serving the boiler with the excess, over the boiler requirement, going to storage for deferred use, e.g. as boiler fuel when milling is discontinued due to mechanical failures.

When the 'Drying and Densification System' is operating, the mill bagasse flow is diverted ahead of the boiler feed through gate 1607T to the pre-screening device, rotary disc screen 1601K. The totality of the mill bagasse flow is directed to the disc screen to ensure the capture of the maximum amount of fines contained in the mill bagasse.

Gate 1608T, mounted underneath the screen,is activated by the dryer control loop such that only that amount of fine bagasse which is commensurate with the evaporative capacity of the flue gasses is accepted as dryer feed. Furthermore, the amount of feed to the dryer is such that a predefined moisture level is obtained at the dryer exit. The fines not accepted by the dryer join the oversized particles from the screen and the blend discharges back into the existing boiler bagasse conveyor which serves the boiler.

The accepted amount of fines is conveyed by conveyors 1613N and 1601N through an airlock 1602N into the rotary dryer 1601F. The purpose of the airlock is to minimize air infiltration into the dryer, since air infiltration would decrease the evaporative capacity of the flue gases.

The boiler waste flue gases are drawn, by fan 1601J through the dryer from ducting 1621T which is attached to the boiler stack(s) or to the boiler induced draft fan(s); in the latter case proper precautions must be taken to ensure complete dissociation between the dryer operation and that of the boiler, moreover this method of tapping the waste flue gases is not the preferred one and should not be attempted if tapping of the stack(s) is possible. It is noted that the system operates under a negative draft to minimize environment dust contamination.

The gas flow through the dryer causes the fine bagasse to be entrained to the cyclone(s) 1603K where the fines are separated from the gas stream. The fines flow through airlock(s) 1603N onto conveyor 1604N. The gas stream is drawn through fan 1601J and vented to stack 1623T. A portion of the gas stream is recirculated through the dryer to maintain a specific velocity.

From conveyor 1604N the fines may be routed, through gate 1609T, directy to the steam mixer/conditioner 1605N/1605K and from there on to a buffering tank 1601S, the purpose of which is to present the densifying unit(s) 1601G with a positive feed.

If the fines exiting cyclone(s) 1603K are not within the size distribution required for densification a secondary screen 1602K is interposed in the flow path between conveyor 1604N and the mixer/conditioner 1605N/1605K. The oversized particles from the screen is routed to conveyor 1610N and thus returned to the bagasse storage to be used as boiler fuel. Gate 1610T mounted under the screen are regulated by the demand of the densifying unit with the excess flowing to conveyor 1610N and thereon back to the existing bagasse storage to be used as fuel. In any event, whether a secondary screen is used or not there must always be an excess of fines, over densification requirements, that is continuously being returned to the boiler as fuel.

The continuous return of that excess stream, being at a lower moisture than the mill bagasse stream, will improve the moisture content of the boiler fuel which is a blend of this excess flow, the oversized particle from the primary screen and that amount of fine obtained from the primary screen that was not acccepted by the dryer. This improved fuel will result in higher boiler efficiency and the generation of larger surplus of bagasse.

A variable speed conveyor 1606N draws the fines from the buffering tank 1601S and regulates the feed to the densifying unit while ensuring that the drive of the latter is at no time overloaded but utilized at an optimal loading high loading being conducive to higher density product. The densifying unit 1601G may either be a 'briquettor' or a 'pelletizer.' The densified bagasse, briquettes or pellets, until properly formed, are rejected into conveyor 1607N which inturn discharges onto conveyors 1610N, 1611N and 1612N. These conveyors return the rejected product back to the existing bagasse storage. When properly formed the densified bagasse is accepted by the cooler 1601E. Ambient air is drawn by fan 1602J through the bed of densified product being carried by the cooler conveyor thereby lowering the product temperature from 120 Deg. C. to approximately 5 Deg. C. above room temperature. The cooling effect hardens the product and prevents condensation of hot vapour from occuring in the storage pile. Condensation in the pile would affect the keeping charateristic of the product.

The cooled product is discharged into conveyors 1608N and 1609N which discharges into a storage bin 1602S. The fines contained in the product entering the cooler are entrained in the air flow to cyclone 1604K and from there, through airlock 1614K, returned to conveyor 1610N.

It is noted that in the event that problems are experienced with the densifier, the dryer can still be maintained in operation because view of the design provisions that allow the dried product to be returned to the existing bagasse storage and from there to the boiler as fuel. These provisions are essential since the dryer requires a long lead time to reach stabilization (predefined moisture level) and because stoppages of the densifier are more frequent than stoppages of the drying system.

Control System

Air intake through the existing stacks is reduced to a minimum, and preferably prevented, by controlling the dampers mounted between the existing boiler stacks and the dryer. These dampers are individually controlled such that their positioning has no resulting effect on the boiler operation and control. Further, air intake at the dryer in let seal flange is minimized by a dryer gas flow and draft pressure control loop. After leaving the dryer, the gases are burdened with the pneumatically transported fines, which are separated out in two large cyclones. The moisture-laden gases are then discharged through the fan to the atmosphere, via a stack. A recycle system, with associated dampers, facilitates the recycling of some of the exhaust gases to the dryer so as to maintain a predefined velocity range.

The RSCS computes the wet-bulb temperature of the mix of boiler flue gasses and air travelling throughout the drying system. Boiler flue gas characteristics, such as humidity and wet bulb temperature, are computed by the RSCS from the following:

(a) Measured On-line Boiler Parameters:

- Steam temperature
- Steam pressure
- Steam flow
- Boiler feed water temperature
- Oxygen content of flue gases
- Dry-bulb temperature of flue gases
- Moisture of bagasse feeding the boiler
- Temperature of bagasse feeding the boiler
- Ambient dry-bulb air temperature
- Ambient air humidity

(b) Off-line parameters:

- Bagasse ultimate analysis
- Boiler uncombustible losses
- Loss due to unburned combustible
- Loss due to radiation
- Loss unaccounted for (such as heat loss with ash, blowdown, etc.)

The established wet-bulb temperature of the air and gas mix travelling through the system is the critical parameter used by the RSCS to define the evaporative capacity of the air and gas mix. The evaporative capacity value is then remotely dispatched to a moisture control loop. This loop then sets the amount of bagasse, from mill bagasse stream, that can be accepted by the drying system.

Material Flow: Once the gas flow throughout the Drying System has been established and a stabilized value of dry-bulb temperature is attained at the gas discharge end of the cyclones, wet mill bagasse is routed through a Feed Gate to a Primary Disc Screen. The Feed Gate is mounted underneath the existing Slat Conveyor which receives the mill bagasse and feeds the boiler.

A proportioning gate, mounted under the screen, directs a portion of the fine bagasse within a specific particle size distribution to the dryer feed. The balance of fine bagasse not accepted by the drying system flows on the "REJECT" side of the proportioning gate and joins the over-sized coarse bagasse flowing from the discharge end of the screen after riding along the upper tips of the discs. This combined flow of fine and coarse bagasse is conveyed back to the existing slat conveyor feeding the boilers.

The amount of fine bagasse directed to the drying system is commensurate to the evaporative capacity of the boiler waste flue gases. A continuous weigher, mounted on the infeed conveyor to the dryer, integrates the weight of fine bagasse accepted by the drying system. The weigher further provides an indication of the feed rate. The moisture content of the fine bagasse to the dryer is also determined on-line by a moisture analyzer.

The proportioning gate moves from the feed end to the discharge end of the screen to satisfy higher feed demands of the drying system. The movement of the proportioning gate is controlled by the moisture control loop. This loop ensures that the dried bagasse is within a specific moisture range (10% to 14%), while utilizing all the available heat contained in the boiler flue gases without reaching the saturation point of gases at the cyclones' exits. The movement of the proportioning gate is limited such that the amount of fine bagasse admitted to the drying system does not exceed the maximum design capability of the system.

Capacity of Briquettor

The capacities of briquetting machines as indicated in the pamphlets of suppliers, refer to ideal materials such as saw dust mixtures containing soft woods and hard woods or similar materials. With bagasse, it is expected that production will fall short by a considerable margin of suppliers' claims. The nominal production rate expected from the largest twin head industrial unit is 2 tonnes/hour of 90 mm diameter briquettes, and maximum output may reach 3 tonnes/hour.

The nominal capacity of the largest unit has been determined, under continuous industrial operation, to be 4.5 to 5.0 tonnes/hour of 9.525 mm diameter pellets, with maximum output reaching 6. 0 tonnes/hour.

Capital Cost Estimate of Briquetting and Pelletizing

As the drying sub-system is essential and similar for either briquetting or pelletizing the investment for that component of the 'Drying and Densification System' has been excluded in computing the capital investments which are proper to the briquetting and pelletizing methods. These investement are shown in the following table for an annual production capacity of 22,903 tonnes, i.e., the case of Wonji:

CAPITAL INVESTMENT
(in $ 1,000)

	Briquetting			Pelletizing		
	Foreign	Local	Total	Foreign	Local	Total
Major Equipment	568	20	588	256	9	265
Erection	-	75	75	-	34	34
Civil/Building	26	26	52	12	12	24
Shipping/Insurn.	46	15	61	21	7	28
Sub-Total	640	136	776	289	62	351
Engineering	39	-	39	17	-	17
Site Supervision	60	-	60	27	-	27
Commissioning	23	-	23	11	-	11
Total	762	136	898	344	62	406

Of the two methods of densification, the investment for the briquetting is higher than that required for pelletizing due to the lower output of the briquettor in comparison to that of the pelletizer, necessitating the purchase of more briquetting units.

Operating Cost of Briquetting and Pelletizing

The case of Wonji has been used to develop the comparative operating costs of the two methods of densification based on an annual production of 22,903 tonnes. From the following table briquetting and pelletizing costs are found to be respectively $3.4546/tonne and $4.4488/tonne inclusive of depreciation.

OPERATING COST
(In $)

	Briquetting			Pelletizing		
	Foreign	Local	Total	Foreign	Local	Total
Depreciation	50,800	9,070	59,870	22,930	4,130	27,070
Insurance	900	-	900	406	-	406
Maintenance	5,290	3,530	8,820	2,387	1,590	3,977
Labour	-	6,528	6,528	-	6,528	6,528
Operating Mtl.						
Fixed Cost	1,800	1,200	3,000	1,240	827	2,067
Variable Cost	-	-	-	61,840	-	61,840
Total	58,790	20,330	79,120	88,810	13,075	101,890

The pelletizing operating cost has been proven, during the past four years in a full scale industrial application, while that of briquetting has not. But in view of the briquettor manufacturers' claims of lower operating cost, the testing of a pilot briquettor is warranted to ascertain the validity of these claims. If these claims are proven true the economic benefits would be quite substantial since the largest component of the operating cost of pelletizing is of foreign origin.

Annex 5

WONJI DEPITHING/BALING PLANT FOR PULP FEEDSTOCK

Bagasse Requirement

For the production of 1 ton of pulp, approximately 3.5 tons of depithed bagasse with 45% m.c. are required. Apparently, the Wonji paper mill plans to install a bagasse pulp mill with a capacity of 28,500 TPA. That is, 28,000 x 3.5 = 98,500 TPA depithed bagasse with 45% m.c. would be required.

Transport of Wet Depithed Bagasse from the Sugar Mills to the Pulp Mill

From the Wonji sugar mill to the pulp mill (1.5 km) a conveying system with blowers (pneumatic) or with pumps (slurry) could be considered. But, from the Shoa sugar mill to the pulp mill, the distance (7 km) is too far for such a conveying system. The same system for transportation should be applied for both sugar mills.

After considering various possibilities, large bales (750 kg each bale) appear to be the most economic solution. The disadvantage of such large bales is that the bagasse will not dry fast enough to prevent excessive fermentation but, since the moist bagasse would only be baled for the transport, i.e., for a few days, this danger is of no significance in this case. Another disadvantage of large bales is that they can only be stacked with expensive cranes. But, once they have arrived at the bulk storage system adjacent to the pulp mill, the bales will be dissolved with water, so no stacking is required in this case. Large bales have the advantage that the wire consumption is substantially less than with small bales.

Small hoists mounted on gantries at the baling station and at the bulk store would be used for loading and offloading. The bulk weight for transportation is approximately 450 kg/cubic meter and no special trucks or trailers would be required for the transport. Cane trailers would be suitable for the transport of the bales. The transport volume from Wonji would be 285 cubic meters per day (128 TPD) and from Shoa 690 cubic meters per day (310 TPD).

Annex 6

DEPITHING/BALING PLANT FOR PARTICLE BOARD FEEDSTOCK

Process Description

The depithing/baling plant would be designed to produce 7,998 TPA of depithed bales for the particleboard plant during 1,504 hours per year and 23,376 TPA of undepithed bales for the sugar mill boilers during 4,396 hours per year.

A conveyor with bagasse from the mill would feed the depithing machine -- when depithed bales are produced -- and the bale press -- when undepithed bales are produced.

Although the boilers are fed with bagasse after the depithing/baling plant, it will still be the boilers which are the dominant consumers, i.e., in case of a shortage there will be no bagasse for the depithing/baling plant.

The remaining bagasse together with the fines which are rejected from the depithing plant, pass through a dryer which is operated with 228 Deg. C. flue gases from the boiler plant. The flue gases are used to dry the remaining surplus bagasse to a m.c. of 12 to 14% to make it suitable for briquetting. The briquetting plant could produce approximately 39,879 of fuel briquettes with 10% m.c.

DRAFT TERMS OF REFERENCE
FEASIBILITY STUDIES FOR PHASES I AND II

Background

A World Bank mission to Ethiopia conducted in January 1985 concluded that the country's sugar industry could generate over 100,000 tonnes (bone dry) of surplus bagasse per year. This is based on present harvest practices, provided that bagasse drying and certain other improvements are carried out at the three existing factories. The pre-feasibility study determined that the following steps will need to be taken to maximize surplus bagasse generation: (1) reduction of steam consumption at the sugar mills by making specific improvements in their boiling houses, and (2) drying bagasse using flue gases and densifying it for use within and outside the mills.

The project will consist of an investigation/evaluation phase, followed by a final design phase based partially on results derived from the first phase. Phase I involves construction of a pilot bagasse briquetting plant, evaluating its technical and financial characteristics, determining market acceptance of bagasse briquettes, assessing the availability and feasibility of using cane tops as a bagasse substitute in the sugar factories, and assessing the feasibility of implementing the factory modifications and large-scale solid fuel processes defined in the pre-feasibility study for the purpose of (i) generating a large surplus of bagasse and (ii) converting the surplus into a densified form for use as solid fuel. Phase II will be the preparation of the final detailed design of factory modifications and densification system required at each sugar factory and the preparation of the tender documents for the industrial application of the final design. The terms of reference for work to be completed in Phases I and II are presented below.

Phase I

Investigation and Evaluation

This study covers five elements which must be completed prior to final detailed design work of Phase II:

(a) detailed design of a pilot briquetting plant to be located at the ESC's Shoa Sugar Factory;

(b) evaluation, after a one crop trial period, of the pilot plant's technical and economic performance to determine which densification system is most appropriate for inclusion in Phase II;

(c) assessing the marketing and distribution systems as well as the social/technical acceptability of bagasse briquettes for household and/or industrial use;

(d) surveying to determine the potential supply of cane tops which could be used to replace bagasse currently being burned to meet internal factory energy needs, and calculating the costs of collecting, storing and using the tops as a substitute; and

(e) assessing the feasibility of implementing the factory modifications and large-scale bagasse densification processes defined in the pre-feasibility study. This assessment will take into consideration the expansion of the Shoa factory, the integration of an alcohol/yeast plant within the expanded factory and results of the above mentioned elements.

These components will be carried out during the first 1.5 years of the project. Details for each component are presented below.

Pilot Briquetting Plant

Undertake the feasibility study for the plant, including:

(a) engineering design of the drying system, consisting of an infeed conveyor, single pass rotary drum dryer fitted with infeed airlock, cyclones fitted with discharge airlocks, induced fan, gas ductings, return conveyor for dried bagasse to boiler, and conveyor for dried bagasse to the briquetting system;

(b) engineering design of the briquetting system, consisting of a buffer bin discharging into a variable screw conveyor, briquetting press, reject conveyor, accept conveyor, product cooler, cooler fan and cyclone, storage conveyor and ducting;

(c) equipment specifications and tender documents for the above drying and densification equipment;

(d) a list of recommended vendors;

(e) foreign and local costs for all drying and densification equipment; and

(f) an implementation schedule for construction of the pilot briquetting plant.

The plant will be located at the Shoa facility and will draw upon the surplus bagasse currently available at that sugar mill.

Evaluation of Pilot Plant Operation

After approximately one crop season of operation, the pilot briquetting plant will be evaluated to assess its technical and economic performance. This involves:

(a) reviewing, summarizing and analyzing operations and maintenance records;

(b) comparing actual capital, installation, operating and maintenance costs of the pilot plant with similar costs of comparable pelletizing equipment in operation elsewhere; and

(c) recommending where the pilot plant's components can be used in Phase II or elsewhere in the country.

Market Acceptability of Briquettes

Drawing on analyses being conducted by the Bank's Agriculture Residue Briquetting Project in Ethiopia, evaluate the effectiveness and efficiency of the system utilized for marketing and distributing bag asse briquettes to household and/or industrial consumers. Assess the social and technical acceptability of briquettes as a substitute fuel in the case of households and the technical performance/acceptability of briquettes as a boiler fuel in the case of industries. Recommend modifications where necessary to improve the sales, distribution and acceptability of briquettes.

Use of Cane Tops

Investigate the potential for generatig additional surplus bagasse through the substitution of cane tops for bagasse in sugar factory boilers by:

(a) conducting yield surveys at Wonji, Shoa and/or Metahara to determine the amount of cane tops available (green and dry basis) as a percentage of cane weight harvested;

(b) determining the percentage of cane tops which should be left in the field as mulch and humus, or for other purposes such as cattle feed;

(c) measuring the moisture content at harvest and the rate of moisture loss of cane tops left in the field, as well as the calorific value of cane tops at various moisture levels;

(d) calculating the optimal time span between harvest and collection of cane tops;

(e) outlining and costing equipment needed for picking, baling, and hauling cane tops to the factory site; and handling and processing cane tops into boiler fuel at the factory site; and

(f) estimating the costs of operating this equipment on an annual basis.

Feasibility Study of Factory Modifications and Large-Scale Production of Densified Bagasse

This element involves the design of mill improvements and large-scale solid fuel production processes. Required work includes:

(a) analyzing the engineering and technical modifications required at FSC's Metahara, Wonji and Shoa Sugar Factories in order to produce and densify an optimal amount of surplus bagasse;

(b) conducting an analysis of the economic and financial feasibility of the overall project; and

(c) outlining and advising on the institutional, managerial and environmental aspects of the proposed project.

The above work will draw heavily on results obtained from investigations and evaluations of the other elements of Phase I. Consultants will work in close cooperation with the Ethiopian Sugar Corporation, which will be responsible for implementing the project.

In the engineering analysis, design and cost estimates will be developed at each plant for:

(a) a system of juice heating using evaporation vapors;

(b) a centralized control system, inclusive of a distributed back-up sub-system, to ensure the proper relationship between live and exhaust steam and evaporation vapors. The control system will also ensure proper relationship between steam and electrical energy generation;

(c) a power factor correction system;

(d) an upgraded tie system to the national grid, inclusive of protective devices and a turbo-generator control system;

(e) the replacement of filter presses (at Wonji and Shoa);

(f) a bagasse reclaim system;

(g) a bagasse drying system;

(h) a bagasse densification system; and

(i) a storage facility, including all conveying systems, to protect and store the densified bagasse.

Based on the equipment specified above, the total cost of the project will be calculated. Then, the economic and financial benefits should be computed, an economic costing of the project should be derived and financial and economic rates of return should be calculated.

Finally, a sensitivity analysis should be conducted to reflect different assumptions about retail pricing of densified bagasse, costs of equipment and operation, market penetration, availability of surplus bagasse, etc.

To determine the full feasibility of the project, a variety of other issues need to be addressed. The roles and responsibilities of all institutions affecting the project should be identified and assessed, and specific recommendations should be made where necessary. Policy and administrative changes that may be needed for successful project implementation should be identified. A detailed implementation schedule needs to be prepared, taking into account the managerial constraints and abilities of all relevant parties. Lastly, the environmental impact of the proposed project should be assessed, both within and outside the sugar factories.

Phase II

Final Design

The work required for Phase II is the preparation of all necessary final design and tender documents for the industrial application of the project at the three factories.

Detailed design documents will be prepared for all aspects of the project. This work should cover:

(a) technical specifications for all factory improvements, densification and storage equipment proposed at each plant and tender documents for the same;

(b) a list of recommended vendors; and

(c) detailed design drawings for local infrastructure (civil, electrical, etc.) at each plant.

SOURCES OF MAJOR EQUIPMENT

1. Drying and Densification System

CLE GROUPE TECHNIP
B. P. 303
33, Quai Gallieni
92156 Suresnes Cedex France

CLE supplies and constructs this system on a turn-key basis and purchases the following major components:

- Dryer from Rader Companies, Inc.
  P. O. Box 20128, Portland, Oregon 97220, U. S. A

or

Rader S. A.
18-20, Place de la Madeleine
75008 Paris, France

- Pelletizer from California Pellet Mill Company
  P.O. Box 6806
  San Francisco, California 94101, U. S. A

or

CPM/Europe S. A.
BP 35-34 Avenue Albert ler
92502 Rueil Malmaison Cedex, France

- Briquettor from F. Hausmann, CH-4006 Basel
  Switzerland

- Control System from Siemens S. A.
  39-47, bd Ornano, 93200 Saint-Denis
  France.

2. Other Dryer Suppliers

- M. E. C Company
  Box 330, Neodesha, Kensas 66757, U. S.A.

- W. Kunz AG. , CH-5606 Dintikon, Switzerland

Note: Flash Dryers have been excluded as the experience with this type of dryer on bagasse application has been disastrous; the same applies to high temperature dryers.

3. Other Briquettor Suppliers

- Gebr. Hofmann, D-8701 Eibelstadt, West Germany

- J. Mared AB, Huskvarna, Sweden

4. Depithing Machines Suppliers

- The Western States Machine Company
  Hamilton, Ohio 45012, U. S. A

- CAL Systems Inc. , Healdsburg, California 95448, U. S. A

- Pallmann GmbH, D-6600 Zweibruecken, West Germany

5. Bale Presses Suppliers

- American Baler Company
  Carl O. Goettsch Company
  Cincinnnati, Ohio 45202, U. S. A

- Lindemann KG., Duesseldorf West Germany

6. Conventional Sugar Factory Equipment Suppliers

In view of their large numbers, suppliers have not been listed for juice heaters, rotary filters, power factor correctors, electrical equipment, etc. The mission recommends that reference be made to the International Sugar Journal Buyers Guide or the F.O. Licht Year Book for listing.

Annex 9
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FINANCIAL COST OF TRANSPORTING PELLETS OR BRIQUETTES

Bulk density = 45 lbs/cuft

Distances:	Wonji/Shoa to Addis Ababa	=	110 Km
	Metahara to Addis Ababa	=	360 Km

Truck: Medium Size (24 tonnes)
C. I. F. Cost : $ 120,000

One trucktrailer can carry 43.4 cu. yds. of Densified Bagasse
= 24 tonnes/load

Fuel consumption = 1.4-1.44 km/liter

Financial Hauling Cost per tonne from Wonji/Shoa to Addis Ababa

Round trip from Wonji/Shoa	=	220 kms
Average speed	=	50 km/hr.
Number of Trips/day	=	2
Total hauled/day	=	48 tonnes
Number of days hauled/year	=	200
Weight hauled/year/truck	=	9,600 tonnes
Total distance/year= 220 x 2 x 200	=	88,000 miles
Total fuel/year = 88,000/1.4	=	62,857 litres
Cost of fuel @ $ 0.376812/litre	=	$23,685
Cost of Lubricants (10% of fuel cost)	=	$ 2,369
Cost of Labor	=	$12,300
Cost of R&M incl. tires = 88,000 x .1768	=	$15,561
Direct Costs	=	$53,915
Provison for write-offs due to accidents	=	15% p.a.
Write-offs cost	=	$18,000
Depreciation (five years)	=	$24,000
Total Cost	=	$95,915/truck

Cost of hauling one tonne of pellets on a yearly basis:
= $ 95,915/9,600
= $ 10.00/tonne

Financial Hauling cost per tonne from Matahara to Addis Ababa

Round trip Metahara to Addis Ababa	=	720 km
Average speed	=	50 km/hr.
Number of Trips/day	=	1
Total hauled/day	=	24 tonnes
Number of days hauled/year	=	200
Weight hauled/year/truck	=	4,800 tonnes
Total distance/year = 720 x 1 x 200	=	144,000 miles
Total fuel/year	=	100,000 litres
Cost of fuel @ $0.376812/litre	=	$ 37,681
Cost of Lubricants (10% of fuel cost)	=	$ 3,768
Cost of Labor	=	$ 12,300
Cost of R&M incl. tires =144,000 x .1768	=	$ 25,459
Direct Costs	=	$ 79,208
Provision for write-offs due to accidents	=	15% p.a.
Write-offs cost	=	$ 18,000
Depreciation (five years)	=	$ 24,000
Total Cost	=	$121,208/truck

Cost of hauling one tonne of pellets on a yearly basis:
= $121,208/4,800 = $ 25.25/tonne

Note: Financial Cost of diesel of $ 0. 376812/liter is from Report 4741-ET, <u>Ethiopia: Issues and Options in the Energy Sector</u>, July 1984.

ECONOMIC COST OF TRANSPORTING PELLETS OR BRIQUETTES

Bulk density = 45 lbs/cu ft
Distances: Wonji/Shoa to Addis Ababa = 110 Km
Metahara to Addis Ababa = 360 Km

Truck: Medium Size (24 tonnes)
C.I.F. Cost: $120,000
Shadow Value: $159,600

One truck-trailer can carry 43. 4 cu. yds. of Densified Bagasse
= 24 tonnes/load
Fuel consumption = 1.4-1.44 km/liter

Economic Hauling Cost per tonnes from Wonji/Shoa to Addis Ababa

Round trip from Wonji/Shoa	=	220 kms
Average speed	=	50 km/hr.
Number of Trips/day	=	2
Total hauled/day	=	48 tonnes
Number of days hauled/year	=	200
Weight hauled/year/truck	=	9,600 tonnes
Total distance/year = 220 x 2 x 200	=	88,000 miles
Total fuel/year = 88,000/1. 4	=	62,857 litres
Cost of fuel@ $ 0.3996/litre	=	$25,117
Cost of Lubricants (10% of fuel cost)	=	$ 2,512
Cost of Labor	=	$12,300
Cost of R&M incl. tires = 88,000 x .1768	=	$15,561
Direct Costs	=	$55,490
Provision for write-offs due to accidents	=	15% p.a.
Write-offs cost	=	$ 23,940
Depreciation (five years)	=	$ 31,920
Total Cost	=	$111,350/truck

Cost of hauling one tonne of pellets on a yearly basis:
= $111,350/9,600 = $ 11. 60/tonne

Financial Hauling cost per tonne from Matahara to Addis Ababa

Round trip Metahara to Addis Ababa	=	720 km
Average speed	=	50 km/hr.
Number of Trips/day	=	1
Total hauled/day	=	24 tonnes
Number of days hauled/year	=	200
Weight hauled/year/truck	=	4,800 tonnes
Total distance/year = 720 x 1 x 200	=	144,000 miles
Total fuel/year	=	100,000 litres
Cost of fuel @$ 0.3996/litre	=	$ 39,960
Cost of Lubricants (10% of fuel cost)	=	$ 3,996
Cost of Labor	=	$ 12,300
Cost of R&M incl. tires =144,000 x .1768	=	$ 25,459
Direct Costs	=	$ 81,715
Provison for write-offs due to accidents	=	15% p.a.
Write-offs cost	=	$ 23,940
Depreciation (five years)	=	$ 31,920
Total Cost	=	$137,575/truck

Cost of hauling one tonne of pellets on a yearly basis:
= $137,575/4,800 = $ 28.66/tonne

Note: Economic Cost of diesel of $ 0.3996/liter is from Report 4741-ET, Ethiopia: Issues and Options in the Energy Sector, July 1984. Presently, the gross excess bagasse, available as 'fuel' and for 'other external factory use', exclusive of 'other factory use', is 13.57% of mill bagasse. Assuming that the expanded factory operates under the same present conditions, the gross excess (13.57% of mill bagasse) would be 6,889 kg/hr or 35,556 tonnes annually.

With the expanded factory, the lime requirement will increase by 34.9% with a corresponding increase in fuel for the lime kiln i.e., from 10,000 to 13,490 tonnes per year or 2,614 kg/hr. Therefore, the net surplus would be 4,015 kg/hr after discounting 260 kg/hr for 'deferred fuel use'.

INDUSTRIAL SECTOR DEMAND

Potential Demand

The total 1982 energy demand in the industrial sector was reported at 167,000 TOE. The distribution of this demand between biomass, electricity and petroleum is presented in Table 1. Almost all the biomass energy is from fuelwood and charcoal which are in scarce supply. The biomass energy in all cases is used to provide process heat. Approximately 50% of the electricity consumption is estimated to be for process heat from electric boilers while over 90% of the petroleum consumption is also estimated to be for process heat with the cement industry being the major consumer.

Table 1: ACTUAL AND FORECAST INDUSTRIAL ENERGY CONSUMPTION
('000 TOE)

	1982	1992
Biomass Fuels	29	96
Electricity	35	98
Petroleum	103	213
Total	167	407
% Share of Total Energy Consumption	2.1	3.7

Source: Ethiopia: Issues and Options in the Energy Sector, July 1984, Joint UNDP/World Bank Energy Sector Assessment Program, Report No. 4741-ET)

Densified bagasse can be used to substitute for a significant portion of present industrial energy consumption. Using the total energy consumption for process heat, there is a potential demand of over 338,000 tonnes of briquettes or pellets. However, not all of the process heat demands can be readily substituted by bagasse. For example, in the cement industry briquettes or pellets can substitute for only about 20% of the process heat requirements without major capital investments. However, industries with fuel oil boilers can, with some equipment modification, convert completely to the use of bagasse. Based on information derived in two recent surveys of Ethiopian industry, it is assumed that 25% of the total industrial electricity demand and 50% of the total petroleum demand can technically be substituted with densified bagasse. This, along with 100% of industrial biomass demand, results in a potential technical demand of 224,000 tonnes of briquettes or pellets. Total industrial energy demand is expected to increase to 400,000 TOE by 1992. Using the same assumptions as above results in a potential technical demand in 1992 of 566,000 tonnes of bagasse.

The economically feasible demand for densified bagasse, given the cost of production and transportation, is less than 50% that of the potential technical demand. A detailed survey of potential industrial users was conducted, as part of a similar study on the use of agricultural residue in Ethiopia, 1/ in conjunction with the Ethiopian Ministry of Energy and Mines and the Ministry of Industry. The survey indicated a current potential economic demand of approximately 94,150 tonnes. This demand was further categorized into two levels depending on the technical ease with which potential industries could convert to utilize the bagasse as a fuel. Level 1 demand consists of those industries which required no major modifications to convert to briquettes or pellets. These were generally industries currently using, or with a capability of using, either fuelwood or charcoal. Level 2 contains those industries which would require some modifications to combustion equipment in order to utilize the densified bagasse as a fuel. Potential Level 1 annual demand was estimated at 21,000 tonnes of briquettes (equivalent to the total output of all the briquetting projects) while Level 2 demand was estimated at 73,150 tonnes. The list of Level 1 and 2 industries is presented in Table 2 and 3.

1/ Ethopia: Agricultural Residue Briquetting Pilot Plants for Substitute Domestic and Industrial Fuel. UNDP/World Bank Energy Sector Management Assistance Program, October 1985.

Table 2: LEVEL 1 POTENTIAL INDUSTRIAL DEMAND
Plants Directly Surveyed

Plant(s)	Location	Current Fuel (type & amount/year)	Current Fuel Cost (US$/year)	Briquette Demand (tonnes/year)	Cost of Briquettes (US$/tonne)	Cost of Briquettes ((US$/year)
National Alcohol Distillery	Addis Ababa	Fuelwood 5,400 m^3	193,801	2,000	34.32	68,640
Ethiopian Hardwood and Softwood Board Plant (ETHARSO)	Addis Ababa	Fuelwood 1,500 m^3	19,560	550	34.32	18,361
Edget Oil Mill	Addis Ababa	Fuelwood 1,380 m^3	49,527	660	34.32	22,651
Private Brick Kilns	Addis Ababa	Fuelwood 8,000 m^3 Fuel oil 288,000 liters	437,696 + 74,435			
TOTAL			= 512,131	3,625	34.32	124,410
Tobacco Barns (Awara Melka)	220 km east of Addis Ababa	Fuelwood a/ 3,440 m^3	150,620	1,225	97.73	119,719
Tobacco Barns (Nura Era)	150 km east of Addis Ababa	Fuelwood 1,150 m^3	43,059	430	102.76	42,131
Lime Kilns	120 km west of Addis Ababa	Fuel oil 561,000 liters	145,000	810	124.16	100,570
		Charcoal 525 tonnes (est.)	78,262 b/		43.98	35,624
Tobacco Barns (Awasa)	255 km south of Addis Ababa	Fuelwood 5,000 m^3	141,190	1,700	46.11	78,387
Total Surveyed Level 1 Potential Demand				11,000		

a/ 3,440 m^3 is demand; actual fuelwood supply is 860 m^3, so some tobacco leaves rot in field.
b/ Price of bulk charcoal in Ambo reported by Lime Kiln Plant manager to be $149.07 per tonne. While this seems low, it is used as the least cost source for charcoal.

Table 3: SUPPLEMENTAL LEVEL 1 POTENTIAL INDUSTRIAL DEMAND
Plants not Surveyed

Plant	Current Fuel (type and annual amount)	Current Fuel (cost per year)	Briquette Demand (tonnes per year)
United Oil and Soap Mill (Addis Ababa)	Fuelwood, 21,000 m^3 + (Electric BLR)	N.A.	7,600
Akaki Oil Mill (Addis Ababa)	Fuelwood, 3300 m^3 150 tonnes fuel oil + (Electric BLR)	N.A.	1,200
Nazrawi Kiba Noug Oil Mill (Nazareth)	Fuelwood, 2400 m^3 + (Electric BLR)	N.A.	800
Arsina Mirta Oil Mill (Nazareth)	Fuelwood, 1200 m^3 + (Electric BLR)	N.A.	400
Total Supplemental Level 1 Potential Demand:			10,000
Overall Level 1 Potential Demand (Surveyed plus Supplemental):			21,000

The industries identified in Tables 3 and 4 do not represent a complete list of potential Level 1 and 2 industries since it was based on a limited survey that was conducted over a two week period. However, the list does represent a significant portion of the potential candidates that are within range of the proposed bagasse densification projects.

Table 4: LEVEL 2 POTENTAL INDUSTRIAL DEMAND
Plants Directly Surveyed

Plant	Cost of Location	Fuel Oil Modification (US$)	Fuel Oil Displaced (liters/year)	Briquette Savings (US$/year)	Cost of Demand (tonnes/year)	Briquettes (US$/year)
Cement Plant	Addis Ababa	135,000	20% - 1.68 million b/	434,203	4,000	137,280
Ethiopian Hardwood and Softwood Board Plant (ETHARSO)	Addis Ababa	100,000 a/	726,000 + 750 tonnes fuelwood	187,638 19,568 207,206	2,100	74,818
Ethiopian Chipwood and Furniture Factory Plant (ECAFCO)	Addis Ababa	70,000	324,000	83,739	750	25,740
Cement Plant of Addis Ababa	DireDawa - 380 km east	100,000	20% - 1 million	258,460	2,150	221,918
Cement Plant of Addis Ababa	Muger - 100 km NW	250,000-400,000	20% - 6.5 million	1.68 million	15,000	1,280,000
Total Surveyed Level 2 Potential Demand:					24,000 b/	

a/ This represent the current mix of fuels consumed.
Increasing substitution of briquettes to 50% at the Addis cement plant will generate additional demand of 6,000 tonnes per year.

Table 5: SUPPLEMENTAL LEVEL 2. INDUSTRIAL DEMAND
Plants not Surveyed

Plant	Fuel Oil Substituted Annual Amount	Cost	Modification Cost	Annual Briquette Demand
	(tonnes)	(US$)	(US$)	(tonnes)
St. Georges Brewery	1,450	392,850	180,000	3,500
Addis Tyre	3,000	813,000	180,000	7,330
Akaki Textiles	5,000	1.25 million	270,000	12,000
Modjo Textiles	900	225,350	100,000	2,200
Dire Dawa Textiles	7,000	1.75 million	360,000	17,000
Total Supplemental Level 2 Potential Demand:				42,000
Overall Level 2 Potential Demand (Surveyed and Supplemental):				68,000

ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAM

Activities Completed

Energy Assessment Status Report	Date Completed
Papua New Guinea	July, 1983
Mauritius	October, 1983
Sri Lanka	January, 1984
Malawi	January, 1984
Burundi	February, 1984
Bangladesh	April, 1984
Kenya	May, 1984
Rwanda	May, 1984
Zimbabwe	August, 1984
Uganda	August, 1984
Indonesia	September, 1984
Senegal	October, 1984
Sudan	November, 1984
Nepal	January, 1985
Zambia	August, 1985
Peru	August, 1985
Haiti	August, 1985
Paraguay	September, 1985
Morocco	January, 1986
Niger	February, 1986

Project Formulation and Justification

Panama	Power Loss Reduction Study	June, 1983
Zimbabwe	Power Loss Reduction Study	June, 1983
Sri Lanka	Power Loss Reduction Study	July, 1983
Malawi	Technical Assistance to Improve the Efficiency of Fuelwood Use in Tobacco Industry	November, 1983
Kenya	Power Loss Reduction Study	March, 1984
Sudan	Power Loss Reduction Study	June, 1984
Seychelles	Power Loss Reduction Study	August, 1984
The Gambia	Solar Water Heating Retrofit Project	February, 1985
Bangladesh	Power System Efficiency Study	February, 1985
The Gambia	Solar Photovoltaic Applications	March, 1985
Senegal	Industrial Energy Conservation	June, 1985
Burundi	Improved Charcoal Cookstove Strategy	September, 1985
Thailand	Rural Energy Issues and Options	September, 1985
Ethiopia	Power Sector Efficiency Study	October, 1985
Burundi	Peat Utilization Project	November, 1985
Botswana	Pump Electrification Prefeasibility Study	January, 1986
Uganda	Energy Efficiency in Tobacco Curing Industry	February, 1986
Indonesia	Power Generation Efficiency Study	February, 1986
Uganda	Fuelwood/Forestry Feasibility Study	March, 1986

		Date Completed
Project Formulation and Justification (cont.)		
Sri Lanka	Industrial Energy Conservation-Feasibility Study	March, 1986
Togo	Wood Recovery in the Nangbeto Lake	April, 1986
Rwanda	Improved Charcoal Cookstove Strategy	August, 1986
Ethiopia	Agricultural Residue Briquetting Pilot Project	December, 1986
Institutional and Policy Support		
Sudan	Management Assistance to the Ministry of Energy & Mining	May, 1983
Burundi	Petroleum Supply Management Study	December, 1983
Papua New Guinea	Proposals for Strengthening the Department of Minerals and Energy	October, 1984
Papua New Guinea	Power Tariff Study	October, 1984
Costa Rica	Recommended Tech. Asst. Projects	November, 1984
Uganda	Institutional Strengthening in the Energy Sector	January, 1985
Guinea-Bissau	Recommended Technical Assistance Projects	April, 1985
Zimbabwe	Power Sector Management	April, 1985
The Gambia	Petroleum Supply Management Assistance	April, 1985
Burundi	Presentation of Energy Projects for the Fourth Five Year Plan	May, 1985
Liberia	Recommended Technical Assistance Proj.	June, 1985
Burkina	Technical Assistance Program	March, 1986
Senegal	Assistance Given for Preparation of Documents for Energy Sector Donors' Meeting	April, 1986
Zambia	Energy Sector Institutional Review	November, 1986
Jamaica	Petroleum Procurement, Refining & Dist.	November 1986