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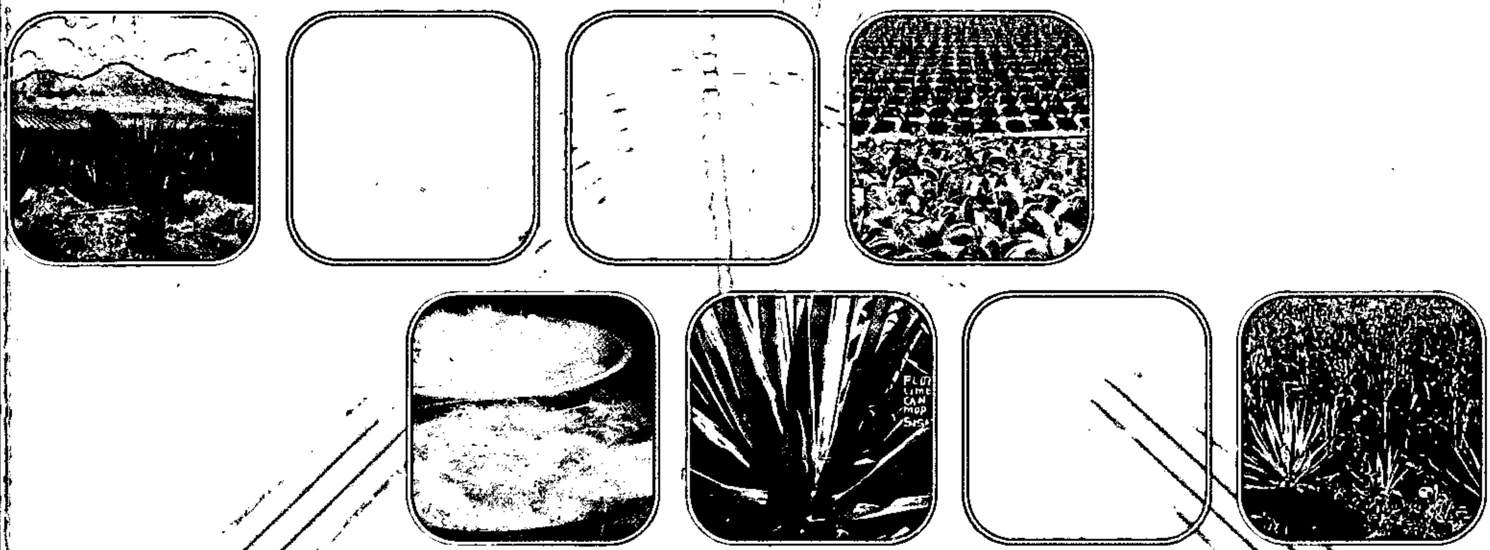
COMMON FUND FOR COMMODITIES
Project CFC/FIGHF/07



Product and market development of sisal and henequen



# Screening and Selection of Technology for Production of Pulpable Fibre

Project completion report/Addendum C.1

Tanzania, Hale Estate, January 1997–June 2004

COMMON FUND FOR COMMODITIES

Product and market development of sisal and henequen

Project completion report, Addendum C.1

# Screening and Selection of Technology for Production of Pulpable Fibre

Tanzania, Hale Estate
January 1997–June 2004

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2006

Project Completion Report preparation: National and international experts and consultants involved with the project, with contributions and support from the national teams.
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# Project Completion Report

# Sub-component C.1
# "Screening and Selection of Technology for Production of Pulpable Fibre"

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## CONTENTS

## Abbreviations and acronyms

| | |
|---|---|
| AD | Air Dried |
| ADMT | Air Dried Metric Ton |
| AQ | Anthraquinone |
| Bl. | Bleached |
| CCB | Companhia da Celulosa da Bahia |
| CEH | Chlorine (C), Alkaline Extraction (E), Hypochlorite (H) |
| CEPS | COAID Enhanced Production System for Sisal |
| CFC | Common Fund for Commodities |
| cm | Centimeter |
| COAID | Canada Overseas Agro-Industrial Development |
| E | Alkaline extraction |
| FAO | Food and Agriculture Organization |
| FEX | Fibre extraction |
| HM | Hammer Mill |
| Hp | Horse power |
| Hz | Hertz |
| IGGHF | Intergovernmental Group on Hard Fibre |
| IRR | Internal Rate of Return |
| KSB | Kenya Sisal Board |
| LL | Liquid limit |
| m | Metre |
| mm | Millimeter |
| MT | Metric Tonne |
| PCC | Project Coordinating Committee |
| PI | Plastic Index |
| R&D | Research and Development |
| rpm | Revolutions per minute |
| TATC | Tanzania Automotive Technology Centre |
| TNO | The Netherlands Organization for Applied Scientific Research *(in this paper it refers to the TNO Paper Institute)* |
| TOR | Terms of Reference |
| UHDT | Ultra High Density Trials |
| Unbl. | Unbleached |
| UNIDO | United Nations Industrial Development Organization |
| UK | United Kingdom |
| V | Volt |
| WAU | Wageningen University (the Netherlands) |

# I. Project sub-component summary

1. Title: Screening and selection of technology for production of pulpable fibre

2. Location: Tanzania, Hale Estate

3. Starting Date: January 1997

4. Completion Date: June 2004

5. Sub-component external financing – excluding counterpart contribution

6.

| | |
|---|---|
| Total Subcomponent Cost: | US$ 421,413 |
| Of which: | |
| CFC Financing | US$ 395,688 |
| Belgium Government: | US$ 14,105 |
| UNIDO | US$ 12,620 |

# II. Background and context in which the sub-component was conceived

## II. 1 Background and context

Fibre extraction is as old as the sisal plant itself. In large sisal estates sisal fibre is been extracted using stationary decorticators known as Corona. The mechanism of the corona is such that short fibres at the butt end are scraped off with parenchyma during extraction. The fibre ejected together with the parenchyma is of low-grade known as flume-tow, and is recovered manually, carded, baled and used for manufacture of sisal bags and mattresses. Flume tow has a high percentage of parenchyma content, is therefore not suitable for pulping, as it consumes more chemicals and cause excessive foaming during pulp beating. Sisal bole has a considerable amount of fibre, which could not be recovered using stationary and mobile decorticators.

Over the past decades sisal production has steadily declined as a consequence of the decreasing demand for its traditional products. During the design and preparation phases of the project it was concluded that:

(i) Sisal/henequen fibre would continue to face stiff competition in the harvest twine market from synthetic substitutes;
(ii) The decline was expected to continue until a major turn around would occur in traditional markets following the introduction of stringent ecological legislation;
(iii) The survival or revival of the sisal/henequen industries in the long run would depend to a great extension on finding new end-uses for sisal fibres.

During project preparation it was recognized that the use of sisal fibre as raw material for pulp provided a good opportunity for substantial increase in the demand of sisal fibre. Sisal pulp could find application in specialty and semi-specialty papers and as reinforcement pulp in recycled papers. The project initial objective was to utilize the whole sisal plant to be able to produce fibre at a cost of no more than US$ 100/ADMT (air dried metric tonne) to be competitive in the reinforcement pulp market.

However, in order for sisal pulp to make inroads in the reinforcement and semi-specialty and to increase its share in the specialty pulp markets, an appropriate technology had to be developed to extract the fibre. To compete in most pulp market segments, the factory-gate cost for sisal fibre would have to be substantially below the prices for line fibre and the waste from the fibre extraction process should be properly treated to minimize the environmental impact of the activities.

Sub-component C.1 was conceived to develop a process of sisal fibre extraction for pulpable grade and to provide the relative costs and return analysis in a feasibility study for a FEX Plant.

## II.2 Objectives, outputs and targeted beneficiaries

The main objectives of this sub-component are:

- To identify and test alternative technologies to extract sisal fibre suitable for pulping and to select the best extraction technology. The technologies to be developed are to be considered as prototype or demonstration technologies for analysis and evaluations to be conducted to select the most suitable technology. This is to be used in the preparation of the feasibility analysis for a full scale FEX plant.
- To conduct pulping and pulp tests on fibre from trials at Hale and Mlingano aiming at collecting data on the performance of the selected four sisal varieties at different planting densities and different harvesting periods to establish the combination with the highest yield in sisal pulp and quality in terms of strength characteristics and bleachability, at the lowest possible cost.

The expected output includes:

- Detailed reports with the description of the technologies evaluated and the conclusions obtained and the drawings and technical specifications of the equipment constructed for project replication.
- Detailed reports on the pulping trials conducted and on the quality of pulp obtained for different agricultural trials.
- The proposal and the feasibility analysis for a full-scale fibre extraction (FEX) plant.

The targeted beneficiaries are the various stakeholders involved in sisal and in particular:

- Estates involved in sisal growing and processing leaves into fibre, including smallholders;
- pulp and paper mills that use sisal fibre.

# III. Implementation and results achieved

## III.1 Description of the implemented activities

The implementation of C.1 started in 1997 by selecting and contracting an international consultant on sisal fibre extraction technologies for production of pulpable fibre.

The consultant was to review the current fibre extraction technologies through literature review and field visits in Kenya, Tanzania and Europe. The scope of the review and of the field visits, conducted in April-May 1998, was to identify a suitable technology for producing pulpable fibre that could be used to design a sisal fibre extraction demonstration plant to be constructed in Tanzania. The main conclusion of this evaluation was that none of the technologies applied in the past using sugar cane crusher, laboratory roll crusher and disc refiners were developed enough to allow their use as the basis for the design of a sisal fibre extraction demonstration plant.

The consultant recommended training cum laboratory research for three African engineers/technicians at the Wageningen University, the Netherlands. The training would include fibre extraction experiments using the extraction equipment and the pulping digester available at the University and also pulp characterization tests to be conducted at the TNO Paper Institute, Delft, the Netherlands. In addition to that, a study tour to Brazil and Mexico in April 1999 was organized for the National Project Officers from Kenya and Tanzania.

Two engineers/technicians from Katani Ltd., Tanzania, and one from Kenya Sisal Board (KSB), Kenya, were trained at Wageningen University (WAU) and TNO Paper Institute from 11 June to 20 November 1999. The trainees conducted fibre extraction trials using horizontal hammer mill, kneader, disc refiner, and roller mill.

The best results were obtaining after nine passes in the roller mill, addition of water during each pass and washing between passes. The fibres obtained from leaf and bole samples of different ages were pulped. The pulps of two samples were bleached using CEH (Chlorine, Alkaline Extraction, Hypochlorite) sequence and the properties of bleached and unbleached pulp were determined at TNO Paper Institute. The results obtained during the training period are indicated in section III. WAU technicians and professors carried out monitoring and supervision of the fibre extraction and pulping activities.

Although the fibre obtained at WAU using the roller mill was clean and had low parenchyma content (3-4% of dry fibre) and the unbleached pulp properties from leaf and leaf/bole mixtures were reasonable (with the exception of tear index), UNIDO considered that the technical information collected during the training was not sufficient to recommend the roller mill as the fibre extraction technology for the demonstration plant for the following reasons:

1. The roller mill used was a laboratory prototype and WAU was not able to provide any information about a supplier of pilot or commercial scale units

that could be consulted and that could advise on production capacity and prices available;
2. The conclusion included in the training report indicates that more research was need and recommended to construct a test rig for further research. Furthermore the roller mill had never been used for production of pulpable fibre at commercial scale;
3. To produce clean fibre, nine passes and washing were required and this entailed nine roller mills in series. A demonstration plant that operates continuously would require other equipment such as driven motors, pumps, pipes, buffer tanks etc. The investment and operational costs in this case might be prohibitive and the demonstration plant not feasible;
4. The tests carried at WAU using a horizontal hammer mill did not provide good results. Information, however, provided by a Brazilian expert contracted by UNIDO and former manager of Companhia da Celulosa da Bahia (CCB) indicated that vertical hammer mills were successfully utilized for production of pulpable fibre for the pulp mill in six FEX plants owned by CCB. The hammer mill was based on the one used for sugar cane bagasse depithing and modified by the company for processing sisal chips. The modified vertical hammer mill developed by CCB was the only equipment used at commercial scale worldwide.

For the reasons above-mentioned UNIDO presented to the Project Coordinating Committee (PCC) meeting held at the end of 1999 a proposal for a new study tour to Brazil. The scope of the study tour was to

- Collect more information on the FEX technology used by CCB;
- Verify whether some modified hammer mill was still available and could be used for trials with African sisal or eventually be transferred and installed in Tanzania;
- Gather more information on research and development (R&D) activities carried out by CCB.

The proposal was approved and a second study tour (February-March 2000) was organized to Brazil for the former manager of CCB and the two engineers from Tanzania trained at WAU also participated in the study tour.

From the facts found during the visits it could be concluded that a FEX investment would be much more realistic if the process used is the hammer mill technology developed by CCB. Unfortunately, at the time of the study tour all the hammer mills owned by CCB had been dismantled and sold as scrap material by the company that took over from CCB. However, it was possible to contact the engineer that designed the equipment and he informed that he could prepare the manufacturing drawings for a prototype. A proposal in this connection was submitted to and approved by the PCC meeting held in June 2000.

The engineer was contracted at the beginning of 2001 to prepare the manufacturing drawings of a prototype hammer mill including a feeding system. The nominal capacity of the prototype is 8.5 tonnes dry fibre/day (20 hours/day).

Tanzanian companies with experience in equipment manufacture were invited to participate in the competitive bid for the construction, installation and commissioning of the hammer mill prototype based on the Brazilian drawings. The Tanzanian Automotive Technology Centre (TATC) was selected by UNIDO and contracted in March 2002.

The contract was then amended in 2003 to include the support structure of the hammer mill; a feeding belt conveyor to transport the sisal chips to the first screw conveyor, and a trolley. The hammer mill prototype was installed at Hale Estate (owned by the project counterpart Katani Ltd.) and started operation in April 2003. Katani Ltd. carried out the monitoring and supervision of TATC.

During the 2000 study tour to Brazil it was found that CCB had modified a mobile forage machine to reduce sisal leaves to chips of suitable dimensions to feed the hammer mill. Both the producer of the forage machine and the Brazilian workshop that had worked with CCB in the modifications were contacted, but the producer was unwilling to provide their services and the workshop submitted a very high quotation. Therefore two mobile forage cutting machines and one trolley produced by the company Jumil, Brazil, were purchased and modified by TATC to produce sisal chips of about 7cm length. TATC was contracted in June 2003 and the modified machines were delivered and operational about one year later. Katani Ltd carried out. monitoring and supervision of TATC contract.

In 2002 Katani Ltd. submitted to UNIDO a proposal for the construction of a small roller crusher for the extraction of fibre of small samples collected in the agricultural trials being conducted under sub-component A.3. The proposal was approved and a contract for the construction of the crusher based on the design and specifications prepared by Katani was awarded to TATC in September 2002 (see final report TATC.) The equipment was delivered and operational at Hale estate in December 2002. Katani Ltd. carried out monitoring and supervision of TATC contract.

Local contracts were awarded to Katani Ltd. to perform pulping trials, to evaluate the quality of the pulp obtained and to evaluate the feasibility of the process. In particular the contracts covered:

- Pulping and pulp evaluation from the agricultural trials, including the 3-factor variety trials (contract 4/2002, August 2002);
- Pulping and pulp evaluation from agricultural trials (A.3).
- Select the optimal technology for the FEX plant
- Prepare a feasibility study for a FEX Plant.

Other activities were subcontracted as part of sub-component C.1:

- Chemical analysis of sisal waste from the effluent of the decorticator, of the hammer mill and of the flume tow recovery plant (contracted to the University of Dar es Salaam in December 2004);
- Civil construction works required for the installation of the hammer mill (contracted to New Builders Ltd. in December 2002 after evaluation of offers submitted by four different companies).

## III.2 Fibre extraction trials at the Wageningen University

The activities were conducted at the department of food processing of the university. The department owns a wide range of equipment to perform size reduction activities. The fibre extraction from sisal could be expressed as a modified size reduction process. Several extraction methods were tried and trials performed using a:

- hammer mill (it has a horizontal shaft on which sharp knife type crushing bars are mounted, underneath there is a screen to allow particles to pass through);
- kneader (a rectangular chamber with the bottom surface raised in two arcs meeting at the centre; the surfaces of these arcs have diamond shaped roughness with sharp peaks);
- roller mill (it consists of two cylinders, each with a rough surface of spiral strips, revolving towards each other in a horizontal plane);
- disc refiner (or sprout Waldron, it consists of a housing holding a stationary face and a revolving disc).

Extraction trials were also performed combining in series the kneader and the hammer mill.

The results achieved are summarized in Table 1.

**Table 1:** Summary of fibre extraction trials results

| Performance parameters | Extraction process | | | | | |
|---|---|---|---|---|---|---|
| | Horizontal hammer | Kneader | Kneader-Horizontal hammer | | Roller crusher | Disc refiner |
| | HH | K | K-HH | HH-K | R | R-D |
| Operating conditions | Poor | Poor (jamming) | Poor (material stack in HH grooves) | Poor | Good | Medium |
| Water add to equipment | no | no | no | no | yes | yes |
| Washing after passes | n.s. | n.s. | n.s. | n.s. | yes | n.s. |
| Washing end | yes | yes | yes | yes | yes | yes |
| Passes in the equipment | >2 | >2 | 1K,2 HH | 1HH, 1K | 9 R | 3 R+6 D |
| Fibre cleanness | Poor | Poor | n.a- no fibre out HH | Poor | Good (3-4% parenchyma) | Good (5% parenchyma) |
| Fibre yield | n.a | n.a | n.a | n.a | 4-5.5% | 4% |
| Fibre uniformity | Poor | Poor | n.a- no fibre out HH | Poor | Good | Poor |
| Fibre damage | High | High | n.a- no fibre out HH | High | Low | High |
| Water consumption | n.a | n.a | n.a | n.a | 100 l/kg | n.a |
| Raw material handling capabilities | Medium | Low | Low | Low | Good | Medium |
| Raw material pre-treatment | Chopping | Chopping | Chopping | Choppin g | Chopping | Chopping |
| Process flexibility | Poor | Poor | Poor | Poor | Good | Poor |
| Demo FEX plant | Not suitable | Not suitable | Not suitable | Not suitable | Need more research | Not suitable |

n.s. : not specified - n.a. : not available

As can be observed in Table 1, the best results were obtained after nine passes in the roller crusher. The quality of the extracted fibre was considered satisfactory (fibre yield was 4% for leaves; 5.5% for a mix of 20% bole material and 80% leaves) and the trainees concluded that more research was required before a decision could be made on the technology to be used for the FEX plant.

Pulping trials were conducted on fibre extracted with the roller crusher using the following cooking conditions:

- Chemical charge: 15% as NaOH on dry fibre
- Time to maximum temperature: 90 minutes
- Time at maximum temperature: 90 minutes
- Maximum temperature: 173° C

- Cooking pressure: 7.5 bar gauge
- Bath ratio: 1:4

The results of 13 cooks are included in Table 2.

**Table 2:** Summary of pulping trials results

| Cook No. | Fibre- Roller mill | | Results | Remarks |
|---|---|---|---|---|
| | Origin | Quantity (Kg) | | |
| 1 | Leaf (8 years) | 3 | Uneven cook | Selected Pulping conditions |
| 2 | Leaf (8 years) | 2 | Uneven cook | Selected Pulping conditions |
| 3 | Leaf (8 years) | 2 | Uneven cook | Selected Pulping conditions |
| 4 | Leaf (8 years) | 1 | Uneven cook | Selected Pulping conditions |
| 5 | Leaf (8 years) | 1 | Uneven cook | Selected Pulping conditions |
| 6 | Leaf (8 years) | 1 | Uneven cook (normal and overcooked) | Selected Pulping conditions |
| 7 | Leaf (8 years) | 2 | Uneven cook | Selected Pulping conditions |
| 8 | 20% bole, 80% leaf (4 years) | 2 | Hard cook | Selected Pulping conditions |
| 9 | Leaf (4 years) | 1 | Uneven Normal cook | Selected Pulping conditions |
| 10 | 20% bole, 80% leaf (4 years) | 1 | Uneven cook | Selected Pulping conditions |
| 11 | Bole inner core (4 years) | 1 | Hard cook | Re-cooked 5% NaOH , 30 min |
| 12 | Bole but-end (4 years) | 1 | Hard cook | Re-cooked 5% NaOH , 30 min |
| 13 | 25% bole inner core, 75% bole but-end (4 years) | 0.5 | Hard cook | Chemical charge 18% NaOH |

The digester performance was not good and gave non-uniform cooks and this was evident when the feed was relatively high (about 3kg air-dried (AD) fibre).

The properties of the unbleached pulps obtained in cooks 6, 8, 9, 10, 11, 12, 13 were determined at TNO. Sample of the pulps 9 and 10 were bleached using a CEH (Chlorine (C), Alkaline Extraction (E), Hypochlorite (H)) sequence and the bleached pulp properties are reflected in Table 3.

**Table 3:** Summary of bleached (Bl.) and unbleached (Unbl.) pulp properties

| **Cook No.** | **6** | | **8** | **9** | | **10** | | **11** | **12** | **13** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Pulp** | **Leaf pulp (8 years plant)** | | **20% bole, 80% leaf (4 years plant)** | **Leaf (4 years plant)** | | **20% bole, 80% leaf (4 years)** | | **Bole inner core** | **Bole butt-end** | **Butt-end, inner core** |
| | ***Unbleached*** | | ***Unbl.*** | ***Bl.*** | ***Unbl.*** | ***Bl.*** | ***Unbl.*** | ***Unbl.*** | ***Unbl.*** | ***Unbl.*** |
| | **Normal** | **Over cooked** | | | | | | | | |
| CFS range | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| Basis weight ($g/m^2$) | 59 | 66 | 63 | 72 | 59 | 66 | 67 | 69 | 67 | 64 |
| Tensile strength (kN/m) | 5.2 | 3.2 | 5.0 | 3.4 | 5.0 | 4.5 | 5.3 | 3.5 | 2.5 | 2.2 |
| Breaking Length (km) | 8.9 | 4.9 | 8.0 | 5.0 | 8.6 | 6.7 | 8.1 | 5.1 | 3.8 | 3.5 |
| Burst strength (kPa) | 335 | 196 | 324 | 115 | 341 | 274 | 412 | 203 | 103 | 94 |
| Burst index ($kPa.m^2/g$) | 5.7 | 3.0 | 5.2 | 1.6 | 5.8 | 4.0 | 6.2 | 2.9 | 1.5 | 1.5 |
| Tear strength (mN) | 485 | 413 | 483 | 166 | 504 | 348 | 636 | 467 | 208 | 244 |
| Tear index ($mN.m^2/g$) | 8.2 | 6.3 | 7.7 | 2.3 | 8.5 | 5.3 | 9.5 | 6.8 | 3.1 | 3.1 |

Note: Kappa number and brightness are not reported.

The strength properties of normal unbleached pulp produced in cook No. 6 were similar to the properties of the unbleached pulp produced in cook No. 9 indicating that the age of the leaves does not have a strong influence in the unbleached pulp characteristics. The properties of the overcooked pulp obtained in cook No. 6, however, were much lower than for normal pulp. The breaking length (8.0-8.9 km) of the unbleached leaf and bole/ leaf mixture pulps produced in the selected cooks was comparable to pulp from line fibre decorticated by the corona (6-8 km). The tear index (7.7- 9.5 $mN.m^2/g$) of the unbleached leaf and bole/leaf mixtures, however, were lower than pulp obtained from line fibre (about 20 $mN.m^2/g$). The properties of the bole inner and butt-end fibres pulps were lower than the leaf and leaf/bole mixture. Since the pH of the alkaline extraction stage (E) was not controlled the properties of the bleached pulps were much lower than the unbleached pulp indicating some degradation of the pulp during this treatment.

## III.3 The hammer mill

### III.3.1 Hammer mill design

As mentioned in section III.1 the construction of a prototype roller mill was not recommended and further investigations on the equipment developed and used in Brazil were undertaken. From the facts found during the visit to Brazil in February 2000, it was concluded that a FEX investment would be much more realistic if the process used were the hammer mill and that the non-satisfactory results obtained at the WAU were due to limitations in the equipment that had originally been designed to grind cereals. The hammer mill was to be installed at Hale estate.

The project contracted a CCB engineer to prepare the manufacturing drawings of a prototype hammer mill including the feeding system (rotating dosing feeder and two helicoidal conveyors). As mentioned, the equipment developed by CCB was dismantled and sold as scrap material; the drawings were destroyed when the company was closed. Intensive search was done also for the mobile chipper equipment, but it was not possible to find it.

Three sets of drawings were submitted to UNIDO in June 2001 (complete list is included in Annex 1):

Set 1- Vertical mill, base structure and layout of defibering plant at CCB (27 drawings);
Set 2- Rotating dosing feeder (6 drawings);
Set 3- Helicoidal conveyors (12 drawings).

The nominal capacity of the prototype is 8.5 tonnes dry fibre/day (20 hours/day) and the design is based on the hammer mill technology developed at CCB for extracting pulpable fibre from sisal.

### III.3.2 Hammer mill description

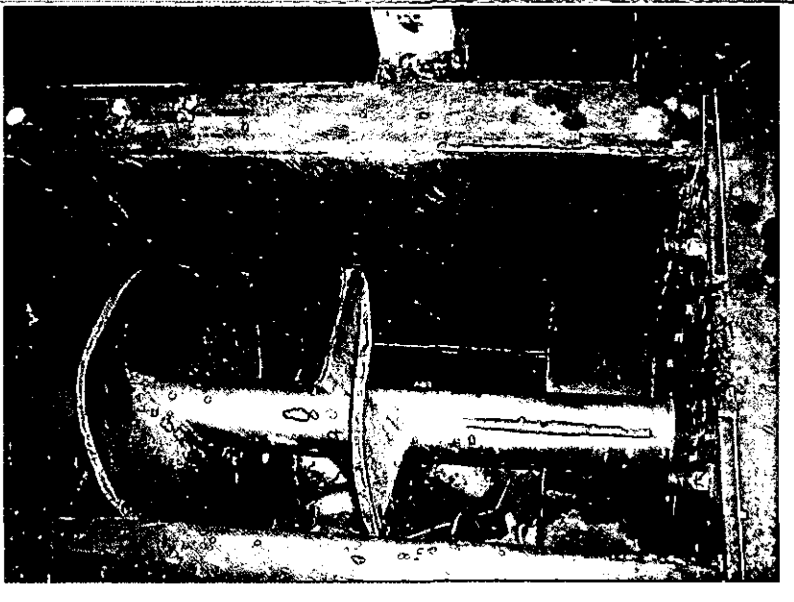
The plant works along the same principle as that of conventional hammer mills with a *production capacity of 9.6 tonnes of sisal chips per hour (slightly higher than the* nominal capacity) and weighs about 14 tonnes. It is exclusively designed for estate production and comprises two main systems: (1) the feeding system for transportation of sisal chips from the chips yard to the mill for fibre production, and (2) the mill itself which extracts fibre by separating it from the bonded parenchyma.

A detailed description of the plant components is outlined below:

(a) <u>Helicoidal conveyor Ø 420</u>: The conveyor is a screw type with an overall length of 6000mm, overall width of 500mm and height of 700mm. It includes a drive system, which comprises an electric motor, gearbox and flexible coupling. The conveyor weighs about 1250 kg and has a carriage capacity of 24 tonnes of sisal chips per hour, enough to supply sisal chips to two vertical mills. It is provided with an overflow spout for collection of excess sisal chips, for reprocessing. The conveyor has three mounting pads and is fitted to the support structure by six bolts; two on each mounting pad. The conveyor is used for transporting sisal chips from the transport conveyor to the vertical mill via the rotating dosing feeder and helicoidal conveyor Ø 280.

(b) Rotating dosing feeder: The rotating dosing feeder is a drum type sisal chip feeder, with variable feeding capacity ranging between eight and 15 tonnes of sisal chips per hour. The speed of the feeder is regulated by using a frequency inverter system, which controls the flow rate of the sisal chips into the vertical mill, in order to meet the milling performance requirements. The feeder measures 1200mm in length, 650mm in width, and 700mm in height and weighs about 320 kg. The feeder is fixed, on the outlet port of the helicoidal conveyor Ø 420, by 24 mounting bolts.

(c) Helicoidal conveyor Ø 280: The conveyor is a screw type measuring 2400mm in length, 380mm in width and 440mm in height. The drive system of the conveyor comprises an electric motor and a speed reducer gearbox coupled through a flexible coupling. The conveyor weighs about 380 kg and has a carriage capacity of 11 tonnes of sisal chips per hour. The conveyor is used for feeding sisal chips into the vertical mill, as supplied by the rotating dosing feeder. It has two mounting pads for fixing on the support structure.



**Helicoidal conveyor Ø 280 mm**

(d) Vertical mill: The vertical mill comprises; a 100 Hp electric motor drive with a support structure, bearing set, rotor set, ground plate, table set, screen, scraper drive and discharge spout. The vertical mill is fixed on the foundation slab by 24 anchor bolts. The slab is constructed to sustain minimum operating loads of up to 1500 $kg/mm^2$. The mill weighs about 2000 kg and has a milling capacity of up to 12.5 tonnes of sisal chips per hour. The nominal diameter of the mill is 900mm and is fitted with a rotor system comprising 68 hammers, which rotate at a speed of 1185 rpm.

Other parts were added to the core of the plant: the support structure, a chips transport conveyor to transport the sisal chips to the first screw conveyor, and a wet fibre trolley. These are described below:

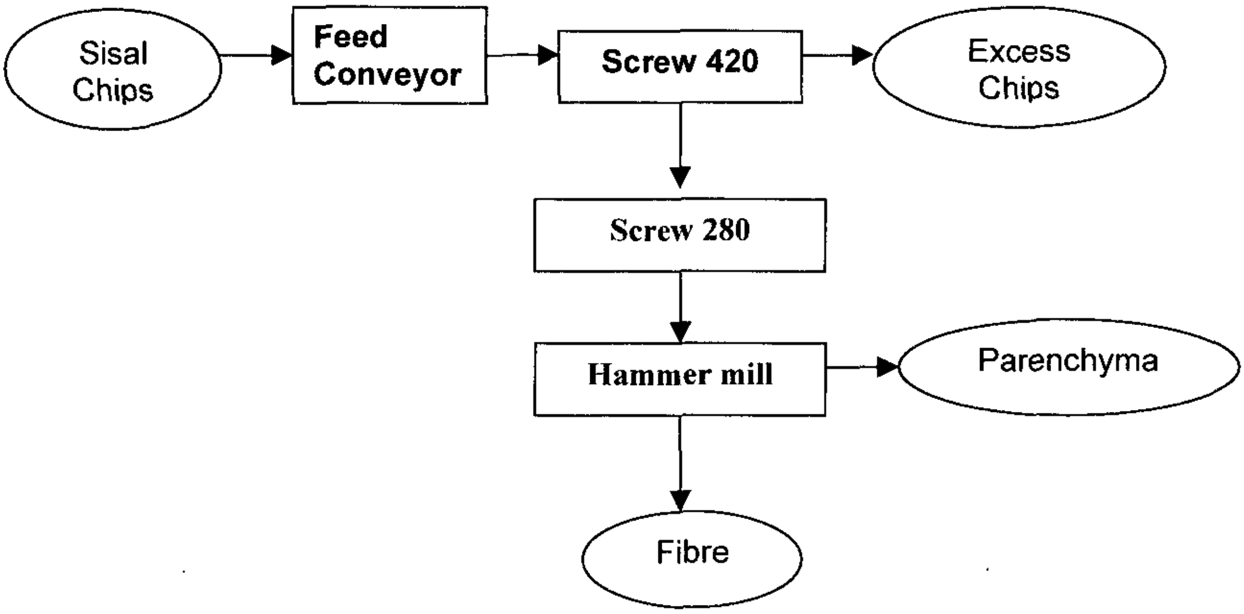
<u>(e) Support structure</u>: The support structure is designed to support the Ø 420 and Ø 280mm helicoidal conveyors and rotating dosing feeder. The structure is also provided with walkways to facilitate efficient operation and maintenance of the hammer mill system and has been installed with protective pipe guides all around the walkways for operator's safety against side fall. The structure is designed to ensure efficient operation and movement of sisal chips from the Ø 420 helicoidal conveyor to the vertical mill.

<u>(f) Chips transport conveyor</u>: The conveyor comprises; a robust main frame, conveyor belt with side supports for protection of sisal chips, sixteen (16) evenly located rollers for supporting the conveyor belt between the driver and driven rollers which are located at each end of the conveyor unit, and a geared motor assembly for provision of power transmission into the conveyor system. The conveyor is essentially used for transporting sisal chips from the receiving yard to the Ø 420 helicoidal conveyor.

<u>(g) Wet fibre trolley</u>: The trolley is designed to meet the requirement of removing processed wet sisal fibre from the hammer mill to the washing bay. The trolley-loading pan is equipped with drop side doors for ease of fibre discharge and is provided with four wheels and a towing handle to facilitate easy transportation of the trolley from one point to another.

<u>(h) Electrics and controls</u>: The plant electrical power supply is three-phase, 380/400V, 50Hz. All system designs have been done in accordance with these supply requirements. The plant electrical system comprises switching and logic control circuits for electric power supply to the vertical mill, the mucilage scraper, the feeding conveyors, the rotating dosing feeder and the transport conveyor. The control system consists of a "fail-safe circuit", *for protection of the entire plant and operators in* case of a fault or breakdown of any of the sub-systems. It is designed to operate on a safe mode logic sequence, that makes it exceptionally user-friendly.

**Figure 1:** Hammer mill fibre production process - block diagram




### III.3.3 Hammer mill manufacture

The contract for the services to manufacture the prototype Hammer Mill was awarded to the TATC, that executed it in accordance with the specifications and the design requirements provided in the Terms of Reference. The TOR spellt out, among other issues, the obligations of TATC as to the manufacture, installation and testing of the hammer mill and its feeding system (i.e. helicoidal conveyors diameter 280mm and 420mm), and a rotating dosing feeder. Together with this obligation, the TOR request TATC to indicate the civil construction and engineering requirements for installation of the hammer mill and its feeding system. Training of Katani staff and the preparation of the Operators Manual and of the Maintenance Manual were also included in the scope of work of TATC.

The main plant systems, i.e. vertical mill, helicoidal conveyors and rotating dosing feeder, constituted a total of 1290 parts out of which 575 parts were manufactured in-house at TATC, 76 parts were subcontracted while the remaining 639 parts were mainly bought as standard items. Most of the project materials and parts have been sourced locally. Foreign purchase involved procurement of: main electric motor, power transmission belts, bearings, electric motor, frequency inverter, geared motors, stainless steel plate and couplings. The rest of the plant systems, i.e. support structure, chips transport conveyor and wet fibre trolley constitute more than 95% fabrication work. All the parts for manufacture were produced locally at TATC and the systems were installed and tested at the TATC workshop prior to transportation to Hale Estate for final assembly.

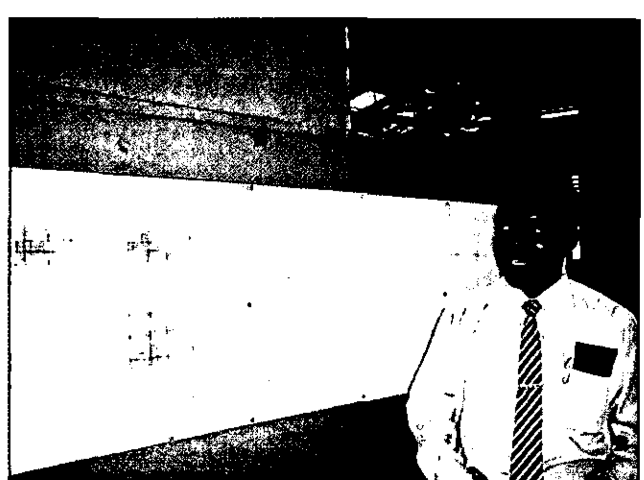
All raw materials and parts were subjected to quality inspection for certification. Inspection was conducted by using supplier's quality control certificates, products specification name plate and in some cases physical measurements of materials was conducted to determine their conformity to specified physical characteristics.

Inspections conducted, indicated that all the supplied raw materials were in conformance to design specifications.

The TATC Project Team comprising 37 personnel from design, production and procurement departments executed the project. Project resources allocation was based on the main project activities to include: procurement and supplies, manufacturing and assembly of parts, parts and units no-load testing, transportation and installation, plant testing and demonstration trials and training of Katani staff.

The following design modifications were considered and implemented during the course of project development:

- Designing the mucilage and sisal fibre supply chutes, as they were not provided in the supplied design package.
- Redesigning the pinion gear, which drives the scraper wheel gear for rotational alignment.
- Redesigning the lower adapter sleeve of the rotor housing in order to direct part of the load to the housing in view of the suspended rotor weight of about 70 kg.
- Redesigning the main motor pulley diameters and motor mounting in order to maintain the hammer mill performance in view of the change of design specifications of the supplied motor.
- Casting conveyor discs instead of metal forming due to thickness of the plate and long lead requirements.
- Designing the bearing housings, which could not be sourced from the specified suppliers.



**Drawings at TATC**

A total of seven new drawings were produced for modification of the hammer mill.

The soil investigation analysis carried out revealed the following results:

- The soil condition for the test depth of 1.5m varied from fine and course soft layer at the top to hard gneissic rock layer at the bottom;
- The liquid limit (LL) and the plastic index (PI) of the upper layer (i.e., 0-0.7m depth) was 29.7 and 7.3% respectively while that of the subsequent layer (i.e., 0.7 – 1.2m) was 37.7 and 18.8%;

- The load carrying capacity of the rock layers found beneath 1.2m depth ranges between 2000 – 3000 $KN/m^2$;
- The soils found from depths up to 1.2 meters have relatively moderate compressibility. The underlying rock layers are absolutely incompressible.

These results were used to design an adequate foundation for the hammer mill. The foundation comprises of a 3.9mx3.45m suspended slab supported on perimeter concrete beams of size 200mmx370mm depth. The slab under the hammer mill is specified as 160mm thick while that in the remaining areas of the foundation it is only 120mm thick. A square opening of 1.34m is provided on the slab as the mill opening while 50mm diameter holes have been specified and provided on the slab for anchor bolts of the motor support, table set and for the safety guides. The slab and the beams have been designed for the specified load capacity of 1500$kg/m^2$. The columns have been designed for loads imposed by the slab and the beams. Column footings have been designed for the loads imposed by the columns.

The design of the slab, beams, columns and the footings has been carried out in compliance with the recommendations of BS8110. Specifications of the selected construction materials are as follow:

- Reinforced concrete; Grade 25;
- Reinforcements; Grade 460 for high yield steel or grade 250 for mild steel rods;
- Cover; 25mm for slab, 30mm for beams, 40mm for columns and 70mm for footings.

New Builders Ltd., a local specialized company, performed the civil works (see Section III.6).

Assembly of the parts and sub-systems was done by using jigs and fixtures depending on the level of assembly accuracy requirement. System assembly was partially done at the TATC workshop and partially on site. Assembly of the units was conducted at sub-system level in order to simplify transportation of the items to Hale Estate (Tanga) for installation work.

### III.3.4 Hammer mill installation, testing and commissioning

The hammer mill sub-systems and components were first packaged for easy handling, transportation, storage and installation and then transported for about 350 km from TATC workshop (Nyumbu) to Hale Estate. The parts were provided with five coats of anti-corrosion and anti-acid resistant epoxy paint prior to shipment. One final coat was also applied after the installation work.

The mill components and parts were assembled at sub-system level. Packaging of the vertical mill, helicoidal conveyors and rotating dosing feeder comprised twenty three wooden crates and water proof materials with a total packaging weight of 6.5 tonnes while that of the support structure, chips transport conveyor and wet fibre trolley also comprised twenty three crates with a total packaging weight of 7.4 tonnes. The trolley was transported to Hale as a complete built unit. Handling of the units was done by factory overheads at the TATC workshops and by mobile cranes, chain blocks and make shift facilities such as ropes, wood and heavy steel pipes at the installation site.

The installation took 25 working days, mostly because of the problems associated with the operating conditions at the site, which restricted the use of mobile cranes and other mobile handling facilities. Details of the installation work are outlined in Table 4.

**Table 4:** Installation activities and schedule

| Begin event | End event | Activity description | Activity duration (No. of days) | Planned earliest start | Planned latest finish |
|---|---|---|---|---|---|
| 1 | 2 | Site preparation | 1 | 11 March 03 | 11 March 03 |
| 2 | 3 | Mounting rotor assembly on table set | 2 | 12 March 03 | 13 March 03 |
| 3 | 4 | Attach discharge chute on table set | 1 | 14 March 03 | 14 March 03 |
| 4 | 5 | Installation of vertical mill on foundation slab | 2 | 15 March 03 | 17 March 03 |
| 2 | 6 | Installation of the hammer mill support structure | 4 | 12 March 03 | 15 March 03 |
| 6 | 7 | Mounting of the Ø 420 helicoidal conveyor on the support structure | 3 | 17 March 03 | 19 March 03 |
| 7 | 8 | Mounting of the rotating dosing feeder on Ø 420 helicoidal conveyor | 1 | 20 March 03 | 20 March 03 |
| 8 | 9 | Mounting of the Ø 280 helicoidal conveyor on the support structure | 2 | 20 March 03 | 21 March 03 |
| 9 | 10 | Mounting the feeding chute | 1 | 22 March 03 | 22 March 03 |
| 10 | 11 | Mounting the overflow chute | 1 | 22 March 03 | 22 March 03 |
| 5 | 12 | Mounting the mucilage chute | 1 | 22 March 03 | 22 March 03 |
| 12 | 13 | Installation of the electrics control panel | 1 | 24 March 03 | 24 March 03 |
| 13 | 14 | Fitting of power supply cables from the CORONA plant to the control panel | 3 | 25 March 03 | 27 March 03 |
| 14 | 15 | Connections of cables to motors | 2 | 28 March 03 | 29 March 03 |
| 15 | 16 | Run test of motors and frequency inverter | 3 | 31 March 03 | 2 April 03 |

A detailed description, which includes many pictures, of the packaging and installation activities was provided by TATC.

On 10April 2003, after completion of the installation work, preliminary testing of the systems for performance demonstration under no load and partial load tests was conducted for five days while for the full load tests the performance demonstrations were conducted for another five days. The test methodology and results were as follows:

(a) No-load test: the tests comprised the introduction of power supply to all drive systems, operating the mill continuously for eight hours a day for three days and observing for any malfunction of the plant components. The results of the tests were as follows:

- The vertical mill rotor set ran smoothly. The rotor dynamic balance was very good as no noticeable vibrations were introduced to the mill slab;
- The scraper crown wheel introduced a bit of noise and vibrations to the mill slab. The problem was caused by the existing design clearance of 2 mm between the crown wheel and support segments, causing the crown wheel to rotate about a translating and rotating axis. The defect was corrected by modifying the pinion wheel which centralized the crown wheel. Subsequent tests showed that the drive system was quiet and smooth.
- The helicoidal conveyors, the rotating dosing feeder and the chips transport conveyor ran quietly and smoothly.

The support structure was checked for system stability by subjecting it to lateral forces. The structure could hardly deflect indicating that it was rigidly stable. All the eight support columns of the support structure are mounted on concrete column bases.

The wet fibre trolley holding capacity is 700 kg of wet fibre and it is adequate for 30 minutes operation of the mill.

(b) Partial load tests: the tests comprised the preparation of 100 kg of sisal chips with approximate lengths between 50 mm and 70 mm. The plant was operated in accordance with the instructions outlined in the operator's manual. Tests were conducted intermittently for 30 minutes, four times a day, for two days. All the sisal chips were transported through the feeding system and decorticated to produce clean and dry fibre through the discharge spout while mucilage was forced through the screen holes to the mucilage chute.

(c) Full load tests and demonstration trials (commissioning): the tests and trials were conducted as follows:

- Chips transport conveyor: It was tested for delivery capacity and was able to transport a total of 400 kg of sisal chips per minute. The conveyor system has demonstrated the capacity to provide sisal chips at the required feeding rate of the mill of 160 kg per minute. The system is dynamically stable during the operation and introduces negligibly small vibrations into the support structure.
- Chips feeding system: It was operated at full load capacity of 400 kg per minute for helicoidal conveyor Ø 420 and 200 kg per minute for helicoidal conveyor Ø 280 and the dosing feeder. No resistance to motion or jamming of the system was evident during the tests. The dosing feeder was then set at the maximum recommended operating speed for achieving the mill feed rate of

160 kg per minute and the chips could easily flow through the feeding system to the mill feeding chute.

- Vertical mill: It produced clean and dry sisal fibre separating it from the mucilage. Parenchyma contamination to the produced sisal fibre was very small and fibre loss through the mucilage was negligible.

### III.3.5 Training of Katani staff

Training was provided in the three main areas of plant operation:

1. Sisal chips receiving yard: chips from the chipping yard are brought to the receiving yard for feeding to the chips transport conveyor. The full capacity charging rate requirement for one hammer mill is 160 kg/min. Two operators are required at the chips receiving yard. No particular skills are necessary for these operators other than general knowledge on the plant operations and safety.
2. Plant control panel: all the plant driving systems including; the main motor, helicodal conveyors Ø 420 and Ø 280 driving motors, rotating dosing feeder frequency inverter, scraper drive motor and the transport conveyor drive unit are operated at the control panel. The panel is fitted with switch buttons for "ON/OFF" operations and emergency stop. The panel also has light indicators for visual observation of the plant system power transmission behavior. The operation and safety of the plant is dependent to a large extent on the skills of the control panel operators. Two operators are adequate to perform all the duties of plant operation, from overseeing the smooth running of the plant systems to controlling and supervising the plant production process.
3. Fibre collection yard: the extracted sisal fibre will be deposited on a wet fibre trolley located at the fibre collection yard. The fibre-loaded trolley will then be moved to the washing bay for further fibre processing. The Trolley carrying capacity is estimated at 700 kg of wet fibre.

**Hammer mill**

Four trainees with basic primary education were selected for basic knowledge training of plant operation. Two of the trainees are for chips feeding to the chips transport conveyor at the chips receiving yard and the other two are for fibre collection at the fibre collection yard. Four other trainees with secondary education were trained for plant operation.

Two other trainees, one for mechanical and the other for electrical maintenance, were selected from among the Katani staff who are involved with daily maintenance of the Hale Estate equipment and the decorticator. These trainees will have a supervisory role on the plant operation and maintenance.

Instructors from TATC and Katani, who have vast experience in plant service and maintenance, sisal fibre processing and installation of electrical systems, conducted training. Emphasis was put on training the selected staff in accordance with their training needs and their areas of specialization and experience, i.e., plant operation, auxiliary plant service, and plant maintenance.

During the training two documents were used as reference material: the "Operators Manual" and the "Maintenance Manual", these describe in full details the activities/actions to be undertaken. Theoretical knowledge was provided to the trainees by way of verbal briefing, training handouts, posters, etc. Operators were also provided with practical training on the operation of the plant systems to include; normal and emergency plant operations. All trainees were tested for their proficiency in the operation, service and maintenance of the plant.

TATC prepared a tailor-made training program that was conducted in two phases. The first phase training program was conducted for five days while the second training program was conducted for ten days as indicated below.

**First phase training program (12 - 16 May 2003)**

| **Description of activities** | **Training days (May 2003)** | | | | |
|---|---|---|---|---|---|
| | 12th | 13th | 14th | 15th | 16th |
| 1. Description of the plant systems and components | ■ | | | | |
| 2. Preparation of the plant prior to starting operations | | ■ | | | |
| 3. Plant and operators safety precautions | | ■ | | | |
| 4. Starting and stopping procedure of the plant | | | ■ | ■ | ■ |
| 5. Sisal chips processing and fibre collection | | | ■ | ■ | ■ |
| 6. Service and maintenance of the plant systems | | | ■ | ■ | ■ |

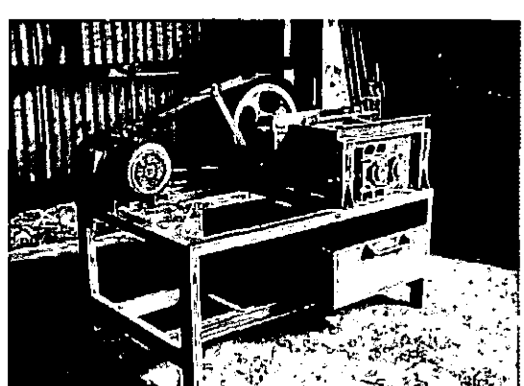
**Second phase training program (5 - 14 August 2003)**

| Description of Activities | Training days (August, 2003) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $5^{th}$ | $6^{th}$ | $7^{th}$ | $8^{th}$ | $9^{th}$ | $10^{th}$ | $11^{th}$ | $12^{th}$ | $13^{th}$ | $14^{th}$ |
| 1. Description of the plant systems and components | ■ | | | | | | | | | |
| 2. Preparation of the plant prior to starting operations | | ■ | | | | | | | | |
| 3. Plant and operators safety precautions | | ■ | | | | | | | | |
| 4. Starting and stopping procedure of the plant | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| 5. Sisal chips processing and fibre collection | | | ■ | ■ | ■ | ■ | ■ | | | |
| 6. Service and maintenance of the plant systems | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| 7. Production trials | | | | | | ■ | ■ | ■ | ■ | ■ |

## III.4 The roller crusher

An important part of the project was dedicated to the agricultural trials; some agricultural trials produced enough material to run the hammer mill while others were smaller and therefore required smaller equipment. Despite the fact that the hammer mill technology was recommended it was decided to design and manufacture a roller crusher to extract fibre from small samples. The roller crusher was designed on the bases of the results obtained at WAU. A contract to design, manufacture and test a roller crusher was signed with TATC in September 2002. The equipment was installed at Hale Estate.

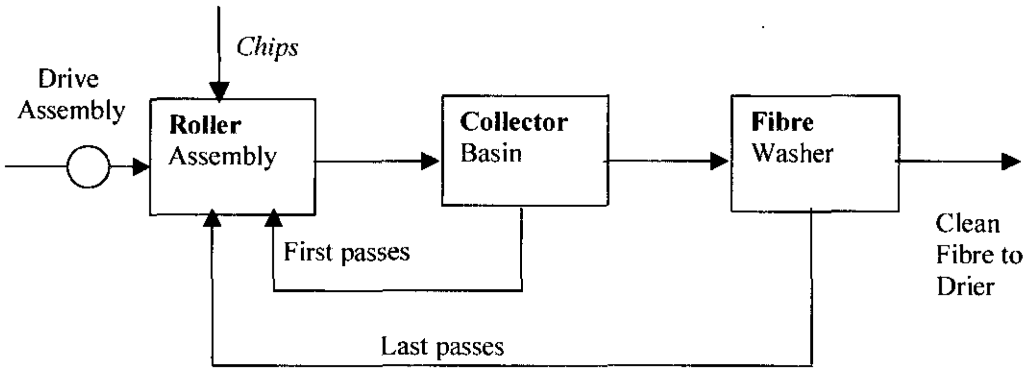
The machine has a feeding capacity range of 0.405 – 2.7 $m^3$/hr of sisal feed/pass (leaves and bole chips) and a production capacity of 0.025 – 0.162 $m^3$/hr of sisal fibre/pass.



**Roller crusher**

The roller crusher is divided into three sub-systems: drive assembly, roller assembly and base frame. The drive assembly provides transmission power from the three-phase electric motor to the reduction gearbox through a v-belt drive system. The roller assembly on the other hand provides the crushing effect of sisal chips for fibre extraction. The system consists of two rollers rotating at relative speeds of 20 and 30 rpm, and is supported on bearings mounted on the side support brackets. The base frame supports both the drive and roller assemblies. Feeding of sisal chips to the crushing rollers is achieved through a hopper, which is integrated to the roller support housing. The process requires sisal chips (from leaves and/or boles) to pass through the set of two rollers rotating at relative velocities for provision of cutting (scratching) and feed motions between the two rollers to facilitate removal of parenchyma and fibre extraction.

**Figure 2:** Roller crusher fibre production process - block diagram




The project was scheduled for eight weeks, but handing over was delayed for eight weeks mainly due to changes in the design of the roller assembly, requested by Katani Ltd.

The project was divided into two main activities of design and manufacturing. Design analysis was conducted for all subsystems, processes and parts for determination and verification of performance characteristics and design specifications and for the preparation of the design package to facilitate production and assembly of the parts. The production process of parts mostly involved casting, turning, milling and drilling.

Quality control and inspection of components and parts was conducted at every stage of production; from receiving of raw materials to final product inspection and certification.

### III.4.1 Performance tests and optimization

Following a first set of tests, the roller assembly was brought back to TATC for design modifications. The main problem with the rollers was in the gap size, which was practically found to be excessive for the intended operation and minimized the scratching effect of the system. The gained experience contributed to improve the design and construction of second prototype roller assembly and the machine was taken back to Hale Estate, for a second set of tests.

Two samples of 256 kg of leaf materials and 198 kg of bole were tested on the machine. Trial production was conducted for a total of 40 hours with an average production rate of 100 kg of sisal chips per eight hours. Fibre from the leaves weighed 13.8 kg, which is approximately 5.4% by weight of the processed sisal chips. Bole material produced fibre weighing 11.5 kg, which is approximately 5.8% by weight.

The drive system operational performance was good. All the other systems worked perfectly except that the production trials conducted on the machine revealed one major problem: trapping of fibre strands on the roller grooves, resulting in fibre destruction as the rollers rotate. Although this problem was eliminated when water was introduced to the process as a scraping media, it was still thought necessary to seek an alternative roller design that would produce clean fibre without the need for water. Among the solutions proposed to solve this problem was the use of diamond indentation rollers, which unfortunately could not be produced at TATC due to the local absence of requisite technology for hot metal platting.

All in all, the roller crusher performed satisfactorily. Sisal chips could be decorticated ready for washing and drying after five to six passes through the rollers. The amount of fibre carrying over has been drastically reduced after the installation of new rollers and introduction of water as a scraping media (see section III.7). Nevertheless it is recommended that:

- Rollers with diamond indentations be sourced for production trials. It is believed that these rollers will improve the productivity performance of the roller crusher significantly.
- The roller crusher be modified to suit the continuous production process requirements. It is recommended that the plant comprises a set of rollers arranged in series, which are adjusted to accommodate specific feed requirements. This will eliminate the need to adjust the roller gap while feeding sisal chips or semi processed fibre into the machine.

## III.5 The sisal chippers

As mentioned in section III.1 CCB had modified a mobile forage machine to reduce sisal leaves to chips of suitable dimensions to feed the hammer mill. Two mobile forage cutting machines and one trolley produced by the company Jumil, Brazil, were purchased and modified by TATC to produce sisal chips of about 7 cm length. The sisal chips are discharged into a trailer and from there into the hammer mill-feeding conveyor.

A contract to design, manufacture and test two sisal chippers was signed with TATC in June 2003. Training of Katani staff was also included in the contract. One forage cutting machine was modified first and used for trials; the second machine was then modified taking advantage of the experience gained with the first one.

Preliminary performance tests were conducted on the first forage cutter to determine the exact design modification requirements. During the experimental stage, the machine was powered by a 7 Hp diesel engine, running at 1500 rpm. The reduction gearbox supplied with the equipment was removed and the engine was directly coupled to the rotor unit through a set of V-belts.

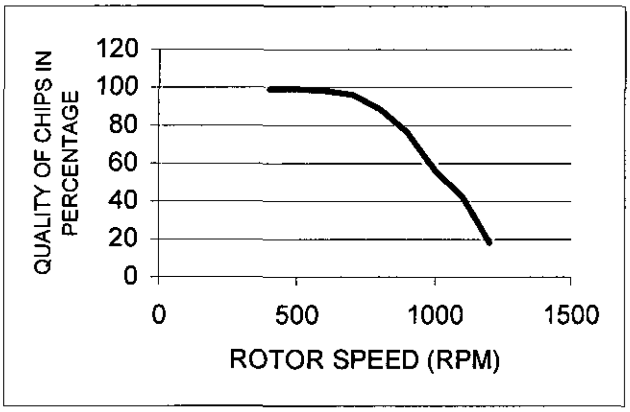
**Sisal chipper**

When the engine was run at maximum speed the tachometer reading at the rotor was 1200 rpm and the output at the hopper was mostly fragmented sisal chips in the form of dust and fibre strands. At 1000 rpm rotor speed however, some sisal chips measuring between 2-5 mm could be produced. It was evident through the preliminary test results, that the rotor speed contributed very much to the quality of the chips produced. At very high rotor speeds, the cut chips were projected at high velocities to the rotor housing where they hit the housing and sprung back to the rotor chamber. The rotor assembly subsequently hit them again and the process continued until the feed became fragmented and assumed a structure, which was light enough to escape through the hopper leaving some of the processed sisal particles stacked on the sides of the hopper.

After the preliminary tests, the machine was subjected to feed testing by using a sample of sisal leaves weighing about 20 kg. Tests were conducted for rotor speeds ranging between 1200 and 400 rpm at intervals of 100 rpm between the tests. The results of the test are graphically represented below. It was observed during the tests that good results were obtained for rotor speeds ranging between 400 and 700 rpm.

For economic performance, the rotor speed of 700 rpm is recommended as the maximum working speed of the chipper. This speed was the basis for design of the system reduction ratio to achieve the specified sisal chips requirement of 40-100 mm long.

**Figure 3:** Graphical representation of the preliminary test results




The design modification work took into consideration all factors pertinent to the function and performance of the system. The design also observed other primary factors such as the safety of the operators and ease of maintenance. Modification work was undertaken in the following areas:

- Power supply (engine mounting structure and pulley drive from the engine to the cutting blades rotor in order to achieve the required rotor speed of 700 rpm);
- Sisal chips cutting blades (the design and materials used for the cutting blades to be changed in order to meet the desired working conditions and properties of sisal leaves);
- Pulley drive assembly from the gearbox to the feeding rollers;
- Gearbox housing;
- Operator's protection and safety.

All raw materials and parts required for the manufacture of the chipper were sourced from the local market with exception of the bare shaft, 7.5 Hp Yanmar L100AE driving engine which was purchased from the UK. All the parts were produced and assembled at the TATC workshops. All purchased raw materials and parts were inspected for conformity to quality standards.

In November 2003, the first prototype chipper was delivered to Katani, Hale Estate, for trial tests. Initial trial tests on the function and performance of the prototype were conducted for one week and the pulley drive assembly was found to be unstable during operation. The design of the pulley drive was optimized and new tests successfully carried out in March 2004. The second chipper was then modified and 29 final drawings and technical specifications prepared.

It was observed that the chipping capacity greatly depends on the skills of the operator. The production capacity ranged from 3.4 to 5.6 tonnes of sisal chips per hour. Two operators are required for effective performance: one operator for supply of sisal leaves and the other for feeding the leaves into the machine.

The machines, which once produced fragmented sisal particles, could produce chips with lengths ranging between 70 and 84 mm. The quality of the chips is good and so is the performance of the machines. However it was not possible to perform a continuous production process for longer than about 20 minutes as the storage trailer could not handle the volume of supply, even under the circumstance where the machine was operating while the trailers were feeding chips to the hammer mill.

## III.6 The civil works

The civil construction activities carried out at Hale Estate were contracted to New Builders Ltd. in December 2002. These included demolitions, excavations, and construction of the concrete foundation (slabs, beams and columns) for the hammer mill.

## III.7 Selection of fibre extraction technology for FEX demonstration plant

The two processes of hammer milling and roller crushing were developed and evaluated. Both technologies offer the potential for efficiently extracting pulpable export fibre from whole plant, leaves and boles. The outcomes of this analysis were used to identify the technology to be adopted for a FEX demonstration plant and to provide required parameters to perform a feasibility study for the FEX plant.

### III.7.1 Roller crusher

As described in section III.4, the first roller fabricated by TATC had deep grooves in one direction and had to be modified to shallow cross grooves. Simulation of the diamond pattern effect was done by using alternating round shallow depressions but this did not perform as envisaged.

Experimental runs were conducted using the crossed shallow grooved rollers with water injection to scrape the fibre. Trials carried out on 16 and 18 April 2004 using sisal leaves from CEPS IIA, showed excessive crushing of fibre due to sticking fibre on the roller surface even after the installation of a water jet system, resulting in fibre damaging in the fifth to seventh stages. Water used was about 39 litres per kg of fresh chips. Unrecoverable fibres were mixed with parenchyma and were difficult to separate, therefore dry weights were estimated. Fibre recovered in sixth and seventh stages had parenchyma content of about 10%. Fibre recovered during these stages was about 3.1%.

A summary of the experimental runs is included in the tables below. Each run was conducted using 28 kg of chips whose average size was 7-10 cm.

Separation of parenchyma was done by shaking the fibre by hand after drying and by removal of parenchyma by hand in soaked fibre. The parenchyma content (%) was determined as:

$$P = \frac{(Wf1 - Wf2) * 100}{Wf1}$$

Where: P = Parenchyma content in % weight basis
Wf1 = Weight of dry fibre (g) before separation of parenchyma
Wf2 = Weight of dry fibre (g) after separation of parenchyma

**Table 5:** Experimental run No. 1

| Pass/ washing | Roller clearance (mm) | Water (l) | Parenchyma dry (g) | Unrecovered dry fibre (g) | Air dry fibre (g) |
|---|---|---|---|---|---|
| | | | | | |
| 1 | 3 | 0 | | | |
| 2 | 2 | 0 | | | |
| 3 | 1 | 60 | | | |
| Washing | -- | 120 | 250 | 4 | |
| 4 | 0.5 | 60 | 0 | 0 | |
| Washing | -- | 120 | 140 | 6 | |
| 5 | 0.5 | 60 | 0 | 0 | |
| Washing | -- | 120 | 245 | 6 | |
| 6 | 0.5 | 60 | 0 | 0 | |
| Washing | -- | 120 | 447 | 50 | |
| Washing | -- | 120 | 504 | 92 | |
| Washing | -- | 120 | 420 | 46 | |
| Washing | -- | 120 | 321 | 15 | |
| **TOTAL** | | **1080** | **2327** | **219** | **884** |

**Table 6:** Experimental run no. 2

| Pass/ washing | Roller clearance (mm) | Time (min) | Water used (l) | | Output Description |
|---|---|---|---|---|---|
| | | | Cleaning rollers | Washing fibre | |
| 1 | 3 | 5 | 0 | 0 | Crushed chips of constant length, not sticking to the rollers, with parenchyma and fibre not detached, no liquid waste. |
| 2 | 2 | 4 | 0 | 0 | Chips more crushed with some parenchyma detached producing liquid waste but no fibre detached |
| 3 | 1 | 4 | 60 | 0 | Some fibre detached from the chips, chips deformed, fibrous mash formed, no fibre damaged |
| 4 | 1 | 5 | 60 | 0 | More quantities of fibre/parenchyma detached, mash slightly white, no fibre damaged |
| Washing | -- | | 0 | 100 | Parenchyma removed, no fibre damaged |
| 5 | 0.5 | 10 | 60 | 0 | More crushing, more fibre/parenchyma detached, fibre damage starts through crushing |
| Washing | -- | | 0 | 100 | Parenchyma removed, short fibres left in wastewater |
| 6 | 0.3 | 7 | 60 | 0 | More crushing, more fibre/parenchyma detached, more fibre damaged |
| Washing | -- | | 0 | 100 | More parenchyma removed, more damaged fibre |
| 7 | 0.3 | 10 | 60 | 0 | More fibre/parenchyma detached but fibre damaged |
| Washing | -- | | 0 | 100 | Some parenchyma removed with damaged fibre |
| Washing | -- | | 0 | 100 | Little parenchyma removed with little damaged fibre |
| Washing | -- | | 0 | 100 | Very little parenchyma and damaged fibre removed |
| **TOTAL** | | | **300** | **600** | |
| **Air Dry Fibre (g)** | | | | | **851** |

The tests with the roller crusher showed that there is fibre damaging between the rollers at the fifth and later stages. Hence it was resolved to run the roller crusher alone, just for comparison, and to use the crusher for the preliminary crushing only in combination with the hammer mill.

### III.7.2 Hammer mill

Single pass trial runs were performed using the hammer mill on 10 March 2004. Sisal was chipped and fed to the hammer mill at a rate of 10 tonnes per hour. This was achieved by spreading 35 kg of sisal chips on the 8 meters belt conveyor. The run took 12 seconds. Fibre and parenchyma were collected at the exits and weighed.

Confirmation of parenchyma-free fibre was done by the use of a microscope.

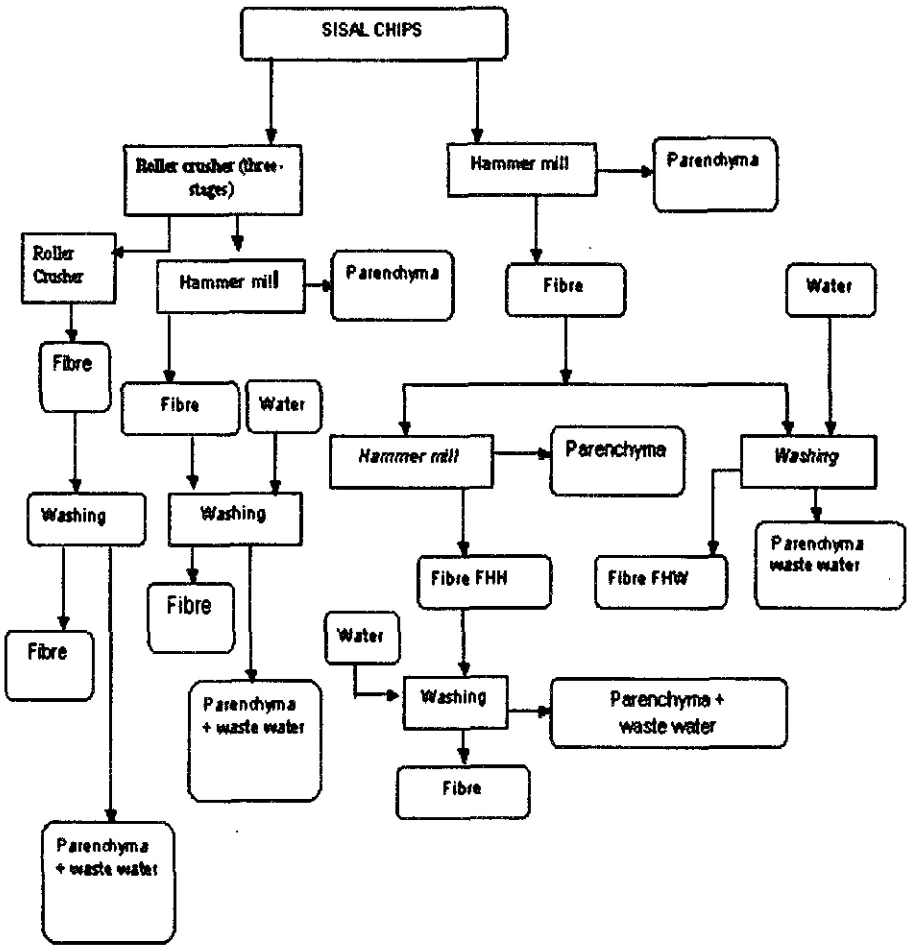
It was generally observed that the fibre weight and parenchyma weight were equal. The fibre had parenchyma content of about 33% similar to the parenchyma content in the fibre extracted by CCB. When water was introduced to the hammer mill at screw conveyor 280 mm, the quality of fibre was still poor with pieces of undecorticated chips. Material loss (see table below) is fibre and parenchyma remaining in the mill when it is run for short time. Fibre losses in the hammer mill are eliminated when the hammer mill is fed continuously (full load operations).

**Table 7:** Experimental run: hammer mill single pass

| Run | Origin | Chips (kg) | Screw conveyor chips (kg) | Wet fibre (kg) | Paren-chyma (kg) | Material loss (kg) | Dry fibre (kg) | Fibre Paren-chyma Content (%) | Fibre Yield (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | CEPS I | 54.8 | 1.2 | 23.4. | 20.5 | 9.7 | 2.2 | 8.9 | 4.1 |
| 2 | -do- | 130 | 2.5 | 58.8 | 55.5 | 12.9 | 5.9 | 11.5 | 4.6 |
| 3 | -do- | 140 | 2.0 | 63.9 | 59.1 | 15.0 | 6.2 | 9.7 | 4.4 |

Considering the results achieved with the roller crusher and with one pass of the hammer mill, a general sequence for the experiments to be conducted to select the technology for the FEX plant was identified. This is represented in Figure 4.

**Figure 4:** General sequence of experimental runs




### III.7.3 Roller crusher – hammer mill combination

Fibre extraction trials using a combination of roller crusher and hammer mill were conducted with the roller crusher performing preliminary crushing of sisal chips in the first three stages and the hammer mill performing more crushing, fibre extraction and parenchyma separation.

The chips were fed into the roller crusher at roller clearance of 3 mm in the first stage, 1 mm in the second stage and 0.5 mm in the third stage. Crushed chips were then fed to the hammer mill screw conveyor with the introduction of water to reduce bulkiness of the material and to facilitate conveyance to the hammer mill.

**Table 8:** Experimental run: roller crusher – hammer mill combination

| Run | Origin of leaves | Chips (kg) | Wet fibre (kg) | Parenchyma (kg) | Material loss (kg) | Dry fibre (kg) | Parenchyma content (%) | Fibre yield (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | CEPS I | 40 | 17.9 | 18.5 | 3.6 | 1.9 | 10 | 4.7 |
| 2 | CEPS I | 40 | 18.5 | 17.3 | 4.2 | 1.7 | 10 | 4.2 |

### III.7.4 Hammer mill second pass

Due to high parenchyma content in the fibre from the roller crusher and /or hammer mill even after washing, it was decided to try a second pass in the hammer mill. Fibre from the first pass was passed again through the hammer mill with intermediate soaking in water to facilitate conveyance in the screw conveyor.

Feeding the mill in the second pass at 0.5 tonnes/hour produced fibre with parenchyma content of 5% before washing, which was reduced to about 4.1% after washing manually. This method was used to produce 5.6 tonnes of fibre for commercial pulping (sub-component C.2). The fibre was visually white and when dried in the sun it became softer than the traditional fibre from the decorticator.

Trials were performed to optimise the feeding in the second pass in order to determine whether it was possible to run two hammer mills in the first stage with one hammer mill in the second stage. Previous trials had shown that fibre produced from the first pass was about 50% of the chips fed to the mill.

Several trials were conducted from 11 to 13 September 2004 to optimise feeding at the second pass. Due to limitation on the feeding chute and accessibility to the helicoidal conveyor 280 mm, it was not possible to simulate feeding of two hammer mills at about 10 tonnes/hour. It was only possible to feed the second pass at a rate of 5 tonnes/hour, but the fibre produced still had about 15% parenchyma content even with increased water use.

A different trial simulating three hammer mills in series with 12 cubic metres of water produced fibre of commercial grade. Water was introduced at the screw conveyor 280 mm in the second and third passes but no further tests were conducted. It was considered uneconomic to use three hammer mills to produce about 3.4 tonnes per shift.

### III.7.5 Washing runs

Washing trial runs were carried out manually to reduce the amount of parenchyma in the fibre. The fibre was washed in batch in seven stages for fibre from the roller crusher and ten stages for fibre from the hammer mill and for fibre from a combination of roller crusher and hammer mill. Parenchyma levels were determined at ARI Mlingano laboratory after drying the fibre.

The washing system supplied by TATC (described in the C.2 report, section III.1.1) was designed based on ten washing stages developed under manual trials. The system was operated but there were some faults and recommendations were sent to TATC for modifications to be effected. The washing system was re-installed after modification but was still found to have limitations in continuous washing of the fibre including accumulation of the fibre at the exit resulting in excessive foaming and low parenchyma removal. The trials were discontinued.

More efforts were put on using two hammer mills with intermediate water spray jets. Twelve more trials were conducted aiming at attaining lower parenchyma levels of less than 10% in the first pass.

### III.7.6 Optimization of parenchyma removal

Specific trials to reduce parenchyma in the first pass were carried out whereby water was injected through perforations in the hammer mill screen in order to dilute the mucilage and facilitate separation by centripetal force. Pressurized water jets were used. Twelve cubic meters of water were consumed per hour although about 30% could not penetrate due to blockage by the mucilage scraper and centripetal force.

The fibre produced in the first pass had parenchyma content of around 15%.

The same method was used in the second pass with six cubic meters of water per hour injected at the screw conveyor 280 mm to reduce bulkiness of the fibre. Another six cubic meters/hour were injected through the screen but only about 70% penetrated inside the hammer mill to dilute parenchyma.

The fibre produced had parenchyma content of about 5%.

More trials need to be done to optimize the water use into the hammer mill.

**Table 9:** Optimization of parenchyma removal using water

| TRIAL | WASHING HAMMER MILL 1ST PASS | | | | | WASHING HAMMER MILL 2ND PASS | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H/M feeding rate | Water jet to screw 280 | Washing system | Water jet to screen | Parenchma content in the fibre | H/M feeding rate tonnes/ h | Water jet to screw 280 | Washing system | Water jet to screen | Parenchma content in the fibre |
| | tonnes/ h | $m^3$/hr | $m^3$/hr | $m^3$/hr | % | | $m^3$/hr | $m^3$/hr | $m^3$/hr | % |
| 1 | 10 | - | - | - | 33 | 0.5 | 3 | - | - | 4.1 |
| 2 | 10 | - | - | - | 33 | 0.5 | 6 | - | - | 6.0 |
| 3 | 12 | - | - | - | 35 | 0.5 | 3 | - | - | 7.0 |
| 4 | 12 | - | - | - | 35 | 0.5 | 6 | - | - | 6.0 |
| 1 | 10 | - | - | - | 33 | 5.0 | 6 | - | - | 18 |
| 2 | 10 | - | - | - | 33 | 5.0 | 9 | - | - | 18 |
| 3 | 10 | - | - | - | 33 | 5.0 | 12 | - | - | 16 |
| 4 | 10 | 3 | - | - | 33 | | | | | |
| 5 | 10 | 6 | - | - | 30 | | | | | |
| 6 | 10 | 12 | - | - | 33 | | | | | |
| 7 | 12 | - | 24 manual | - | 15 | 6.0 | 6 | 24 manual | - | 6 |
| 8 | 12 | - | 24 mecha-nical | - | 28 | 6.0 | 6 | 24 mecha-nical | - | 15 |
| 9 | 10 | - | 24 mecha-nical | - | 24 | 6.0 | 6 | 24 mecha-nical | - | 13 |
| 10 | 12 | - | - | 4.2 | 22 | 6.0 | 6 | - | 4.2 | 12 |
| 11 | 12 | - | - | 8.4 | 20 | 5.0 | 6 | - | 4.2 | 10 |
| 12 | 10 | - | - | 8.4 | 15 | 5.0 | 6 | - | 4.2 | 5 |

### III.7.8 Best sequence to achieve pulpable fibre of commercial quality

From the preformed trials the following observations can be summarized:

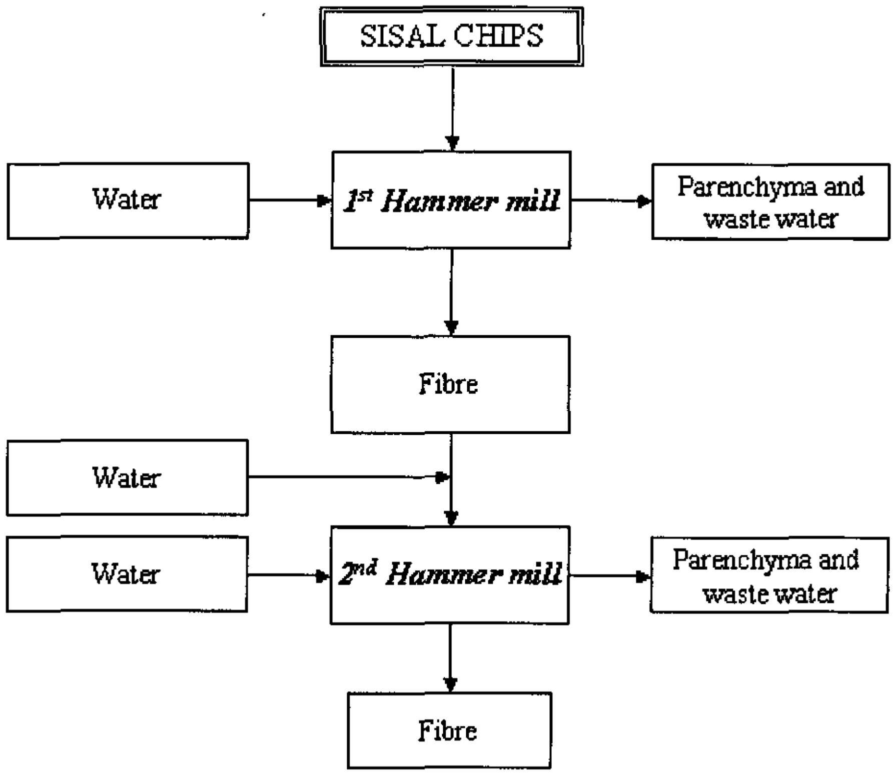
1. **The roller crusher** crushed sisal chips and loosened the parenchyma in the three stages but did not detach it from the fibre. There was no fibre damage at this stage. In subsequent stages, especially fifth to seventh, fibre was damaged due to excessive crushing between the rollers causing the fibre to stick in the roller grooves. This was not observed in the rollers used in the Netherlands, which had a diamond shape surface pattern. The fibre produced had some parenchyma adhering to it, which could not be separated by washing, until the fibre was subjected to mechanical forces. The parenchyma was around 10% by weight. Water used to wash the fibre was around 39 liters per kg of fresh chips, or 1 to 1.2 cubic meters per kg dry fibre. Fibre recovery was about 3.1% of the weight of the chips.
2. **The hammer mill** ($1^{st}$ pass) was able to crush the sisal chips and separate parenchyma through the perforated screen in the first pass. It was observed that not all detached parenchyma was separated from the fibre and there were some pieces of chips, which were ejected without being crushed. The *parenchyma content of the fibre from first pass in the hammer mill was* observed to be about 33% by weight at chips feed rate of 10 tonnes per hour.

Parenchyma content increased at higher feeding rates. The parenchyma separated through the screen had very low fibre content of about 1%.

3. **The roller crusher- hammer mill combination.** It was observed that crushing sisal chips three times in a roller crusher and then making one pass in the hammer mill produced fibre of same quality as one produced by one-pass hammer milling alone. It was realized that a combination of roller crusher and hammer mill did not improve the quality of fibre.
4. **The hammer mill** (second pass). It was observed through trial runs that when fibre produced from a first pass in a hammer mill is passed again in the hammer mill the fibre quality improved. The second pass through the hammer mill crushes the parenchyma, which still adheres to the fibre and contributes to separate more parenchyma from the fibre. Feeding the second pass without washing at 10% of mill capacity produced fibre with parenchyma content of around 5%. The parenchyma content of the fibre could be reduced to around 4.1% after washing.
5. **Feeding and washing**. Feeding the second pass in the hammer mill at a rate corresponding to the output from the first pass produced fibre of low quality with parenchyma content about 15%. Most of the parenchyma was detached from the fibre but could not be separated through the screen. Manual washing of the fibre in the water bath before and after the second pass produced fibre of good quality with parenchyma content of about 5%. Continuous washing of the fibre from first pass in a washing system developed by TATC was hindered by the accumulation of fibre before the end of the washing system. The system requires modification of the exit mechanism to enable picking of the fibre at the end. The screen also needs to be modified to have more openings to allow more parenchyma to pass through. It was observed that introducing water inside the hammer mill at a rate of 8.4 $m^3$/hour through the perforated screen in the first pass produced fibre with low parenchyma content of about 15%. It was also observed that supplying the second pass with 6 $m^3$/hour of water at the screw conveyor 280 mm and 4.2 $m^3$/hour at the screen produced fibre with parenchyma content of 5%.

From the trials performed with different extraction sequences, it was found that the sequence with optimum results in terms of extraction efficiency and output was two passes in the hammer mill with water supplied inside the hammer mill. The sequence is represented in the figure below and a preliminary layout is included in Annex 2.

**Figure 5:** Optimal extraction sequence




III.7.8.1 Mass balance

Sisal chips were fed in the first pass at a rate of 10 tonnes/hour with water jet injected at the screen at a rate of 8.4 $m^3$/hour. The fibre produced was 25% by weight of the fresh chips and had a parenchyma content of about 15%. The extracted fibre was then fed to the hammer mill at a rate of 5 tonnes/hour with 6 $m^3$/hour water injected at the screw conveyor 280 mm, and another water jet at the hammer mill screen at 4.2 $m^3$/hour.

The fibre produced in the second pass was about 50% of the fibre fed to the hammer mill. Parenchyma content was about 5%. The trial confirms that wet fibre from two-hammer mills can be processed by one hammer mill doing a second pass.

Expected production is about 814 tonnes/hour or 5.7 tonnes per shift of eight hours (assuming seven effective hours) or 11.4 tonnes per day assuming two shifts/day.

A mass balance for a system that includes two hammer mills in parallel for the first pass and one in series for the second pass was prepared on the basis of the results of the latest trial (Table 10), performed without a washing system. The mass balance is in Annex 3.

**Table 10:** Trial (1-hour run) to prepare mass balance

| Description | Green Chips | | Fibre 1st pass HM + Washing water | | Washed fibre out put 2nd pass | | Dried Fibre | |
|---|---|---|---|---|---|---|---|---|
| Flow No. | 1 | | 3 | | 4 | | 5 | |
| Composition | % | Kg/hr | % | Kg/hr | % | Kg/hr | % | Kg/hr |
| Fibre | 4.09 | 818 | 14.36 | 718 | 27.48 | 687 | 84.40 | 687.00 |
| Parenchyma | 9.21 | 1842 | 2.56 | 128 | 1.48 | 37 | 4.48 | 36.46 |
| Water | 86.50 | 17300 | 83.00 | 4150 | 71.00 | 1775 | 11.00 | 89.54 |
| Others | 0.20 | 40 | 0.08 | 4 | 0.04 | 1 | 0.12 | 1.00 |
| Total | 100.00 | 20000 | 100.00 | 5000 | 100.00 | 2500 | 100.00 | 814.00 |

| Description | Fresh water for 1st pass HM | | Parenchyma 1st pass HM | | Fresh water for 2nd pass HM | | Parenchyma 2nd pass HM | | Parenchyma 1+2 HM | |
|---|---|---|---|---|---|---|---|---|---|---|
| Flow No. | 1 | | 2 | | 3 | | 4 | | 5 | |
| Composition | % | Kg/hr | % | Kg/hr | % | Kg/hr | % | Kg/hr | % | Kg/hr |
| Fibre | | | 0.32 | 100 | | | 0.24 | 31 | 0.29 | 131 |
| Parenchyma | | | 5.39 | 1714 | | | 0.72 | 91 | 4.06 | 1805 |
| Water | 100 | 16800 | 94.18 | 29950 | 100 | 10200 | 99.02 | 12575 | 95.56 | 42525 |
| Others | | | 0.11 | 36 | | | 0.02 | 3 | 0.09 | 39 |
| Total | 100 | 16800 | 100.00 | 31800 | 100 | 10200 | 100.00 | 12700 | 100.00 | 44500 |

Data:

| | |
|---|---|
| Fibre content in leaf | 4.6% |
| Air-dried fibre yield of | 4.07% |
| Moisture content in fresh chips | 86.5% |
| Moisture content in fibre first pass | 80% |
| Moisture content in fibre 2nd pass | 71% |
| Parenchyma content after first pass | 15% |
| Parenchyma content after second pass | 5% |
| Water added in the first pass (2 mills) | 16.8 tonnes/hour |
| Water added in the second pass (1mill) | 10.2 tonnes/hour |

## III.8 pulping trials and pulp evaluation

The objectives of conducting pulping and pulp tests on fibre from trials at Hale and Mlingano was to:

- evaluate the performance of fibre extraction technologies;
- collect data on the performance of the selected four sisal varieties at different planting densities and different harvesting periods to establish the combination with the highest yield in sisal pulp and quality in terms of strength characteristics and bleachability at the lowest possible cost.

Two contracts were signed with Katani Ltd. (the first one in 2002 and the second one in 2003) to perform the activities.

### III.8.1 Equipment, materials and supplies provided

The contractor provided a stopwatch and two balances, one for weighing sisal leaves and sisal chips, and the other for weighing wet fibre and wet mucilage. The trolley fabricated by TATC was used for receiving wet fibre. Fifteen plastic buckets were used for collecting samples of mucilage, washed fibre and sisal chips including wastewater. Two plastic drums for composite samples.

The Marius oven capacity 0 – 200°C at Mlingano was used to determine moisture content in sisal chips, wet fibre and wet mucilage. The ARI Mlingano Mettler PM 11 analytical balance with an accuracy of 0.01 grams was used for determination of moisture of the wet and dry fibre produced. The muffle at the University of Dar-es-Salaam was used to determine ash content.

To determine mucilage and fibre content of sisal leaf two methods were used. In one case three leaves weighing 1.36 kg in total were cooked (or boiled in an open vessel with water) for eight hours and the fibre separated from the mucilage by hand. In the second case, sisal leaves were chopped and processed in the hammer mill and roller crusher and washed several stages before drying in the sun for 12 hours. The parenchyma was separated from the dry fibre by shaking and weighing the detached parenchyma. The little parenchyma remaining in the fibre was removed by soaking the fibre in water for two days, washed in water and dried. The parenchyma content was determined by reduction on fibre weight before and after the whole separation process. The results were compared visually with line fibre from traditional decorticator using Stemi1000 Zeiss microscope with lens range of 0.7-3.5 at ARI Mlingano.

### III.8.2 Pulping and pulp testing

Pulping of the fibre was carried out at Kibo Pulp and Paper Board Mill laboratory in Moshi. The applied pulping conditions were as follows:

- Active Alkali: 13.5% as NaOH (13.5 kg NaOH/100 kg of dry fibre)
- Heating time to maximum temperature (min): 90
- Time at maximum temperature (min): 90
- Maximum temperature (°C): 173
- Dilution ratio: dry fibre/4 white liquor.

The pulp was washed and dried naturally after cooking and no refining was done. No bleaching was performed (see C.2 report).

Pulp testing was conducted at Southern Paper Mill laboratory in Iringa. The pulp was refined using PFI mill and freeness was determined using a Canadian Freeness Standard tester to around 300 CFS at 0.3% consistency. The kappa number was determined by titration using potassium permanganate and sodium thiosulphate solution. Standard hand sheets were made and used for testing of the physical characteristics of the pulp including tensile strength, tear strength, elongation, tensile energy absorption and burst strength.

Parameters evaluated:

- Cleanliness of the fibre and of the pulp (visual)
- Pulp yield
- Kappa number
- Breaking Length
- Tear strength
- Burst strength

No refining was done. The results obtained are presented in the sections below.

III.8.2.1 Fibre and pulp cleanliness

The following were the observations made on the visual appearance of the last samples (eight leaf samples and three bole samples from CEPS I; two leaf samples from CEPS IIA and IIB and four leaf samples from UHDT and 12 samples of leaf from Mlingano) raw fibre and pulp:

<u>Visual appearance of raw fibre</u>: Sisal fibre was extracted using the hammer mill for Hale samples and roller crusher for ARI Mlingano samples. The hammer mill fibre was close to white but had amorphous parenchyma adhering to it. The fibres were coarse, undamaged and maintained original chip length. Fibre from the roller crusher was close to white but had also some amorphous parenchyma adhering to it. The fibre was relatively soft, looked more crushed and did not maintain the original chip length.

<u>Visual appearance of pulp</u>: Generally the pulp samples had brown color with tiny dark spots. The hand sheets from Hale had some shives (uncooked fibre in pulp) despite refining to around 300 ml CSF. The amount of shives varies from one variety to another. Hand sheet samples of Mlingano pulp had no shives but black spots were observed in all samples.

III.8.2.2 Pulp yield

Data for the first, second, third and fourth harvests of CEPS I is incorporated for comparison in the table below. The fibre extraction was performed with:

| | |
|---|---|
| First harvest: | crusher of the University of Dar es salaam |
| Second harvest: | test rig built by Katani Ltd. (knife drum) |
| Third harvest: | roller crusher |
| Fourth harvest: | hammer mill. |

**Table 11:** CEPS I – Leaf pulp yield (kg AD pulp/kg AD fibre)%, AD = air dried

| Variety | Density plants/ Ha | First harvest (24 months) | Second harvest (33 months) | Third harvest (47 months) | Fourth harvest (52 months) |
|---|---|---|---|---|---|
| **Fibre extraction method** | | Roller crusher | Test rig | Roller crusher | Hammer mill |
| H.11648 | 6400 | 73.1 | 61.7 | 56.6 | 74.3 |
| H.11648 | 8000 | 71.2 | 70.0 | 64.0 | 73.5 |
| Agave Sisalana | 6400 | 69.4 | 73.3 | 60.3 | 75.7 |
| Agave Sisalana | 8000 | 70.6 | 73.3 | 59.2 | 74.7 |
| Agave Hildana | 6400 | 69.5 | 61.7 | 59.5 | 72.9 |
| Agave Hildana | 8000 | 67.5 | 70.0 | 53.3 | 72.6 |
| Mlola 487 | 6400 | 70.2 | 50.0 | 52.4 | 78.5 |
| Mlola 487 | 8000 | 68.6 | -- | 65.5 | 76.1 |

A graphical representation of the data is included in Annex 4.

From the results obtained it can be concluded that generally leaf pulp yields in all varieties in CEPS I are higher in the fourth harvest and lower in the third harvest, when the roller crusher was used. With the exception of the first and fourth harvests, H11648 has shown higher pulp yield in 8000 plants per hectare than in 6400 plants per hectare. Sisalana generally recorded highest yields in all harvests while Mlola recorded high yields in the fourth harvest.

Bole fibre was extracted from CEPS I, fourth harvest, 52 months, with the hammer mill. The results are included in the table below.

**Table 12:** CEPS I – Bole pulp yield (kg AD pulp/kg AD fibre)%, AD = air dried

| Variety - Density | Pulp yield (%) |
|---|---|
| H.11648- 6400-B | 57.5 |
| H.11648- 8000-B | 54.6 |
| Sisalana- 6400-B | 54.1 |
| Sisalana-8000-B | 53.4 |
| Hildana 6400-B | 55.7 |
| Hildana 8000-B | 53.4 |
| Mlola-6400-B | 52.5 |
| Mlola-8000-B | 51.8 |

A graphical representation of the data is included in Annex 4.

Bole pulp yields in the fourth harvest CEPS I recorded an average of 54.1% and decreased with increasing density in all varieties. H11648 at 6400 plants/ha recorded the highest yield while Mlola at 8000 plants/ha recorded the lowest pulp yield.

For the third harvest, 47 months, the fibre was extracted with the roller crusher. The results are included in the table below.

**Table 13:** 3-Factor variety trial – Leaf pulp yield (kg AD pulp/kg AD fibre)%, AD = Air Dried

| Variety | 4000 Plants/ha | 6400 Plants/ha | 8000 Plants/ha |
|---|---|---|---|
| H.11648 | 72.3 | 73.7 | 73.0 |
| Agave Sisalana | 61.4 | 69. 8 | 70 |
| Agave Hildana | 74.6 | 72.1 | 71.4 |
| Mlola 487 | 70.8 | 70.0 | 68.4 |

A graphical representation of the data is included in Annex 4.

Samples from the 3-factor variety trials at Mlingano recorded an average pulp yield of 70.7%. H11648 and Hildana recorded pulp yields above 70% in all densities, while Sisalana at density of 4000 plants per hectare recorded the lowest yield.

Fibre was also extracted for different harvests and using different methods for CEPS II and Ultra High Density Trials (UHDT). The results are included in the table below.

**Table 14:** CEPS II and UHDT trials – leaf pulp yield (kg AD pulp/kg AD fibre)%, AD = Air Dried

| Variety | Density plants/Ha | First harvest (24 months) | Second harvest (33 months) | Third harvest (47 months) |
|---|---|---|---|---|
| **Fibre extraction method** | | Roller crusher | Hammer mill (roller crusher) | Hammer mill |
| CEPS IIA | 6,666 | 54.8 | 74.8 | -- |
| CEPS IIB | 6,666 | 53.3 | 74.2 | -- |
| UHDT | 12,500 | 59.0 | (82.5) | 70.5 |
| UHDT | 16,666 | 35.7 | (68.7) | 69.4 |
| UHDT | 25,000 | 29.5 | (75.0) | 69.7 |
| UHDT | 33,333 | 34.4 | (74.1) | -- |

Generally planting density of 12,500 recorded higher yields in all harvests in UHDT and higher yields in all densities were observed in the second year. CEPS IIA and IIB recorded 64.3% average pulp yield.

III.8.2.3 Kappa number

Generally in CEPS I the kappa number, as shown in Table 15 and in a graph in Annex 4, is high in all varieties, harvests and densities. Slightly higher values are obtained in the first harvest, but there is no clear trend of kappa number in relation to variety, age or planting density. H11648 has the lowest kappa number in the fourth harvest of planting density 6400.

**Table 15:** CEPS I Trials – kappa number

| **Variety** | **Density Plants/Ha** | **Harvest** | | | |
|---|---|---|---|---|---|
| | | First | Second | Third | Fourth |
| H. 11648 | 6400 | 34.8 | 37.8 | 23.5 | 13.6 |
| H. 11648 | 8000 | 21.8 | 28.8 | 33.2 | 25.6 |
| Agave Sisalana | 6400 | 25.7 | 15.0 | 25.7 | 24.0 |
| Agave Sisalana | 8000 | 28.1 | 20.4 | 27.1 | 26.6 |
| Agave Hildana | 6400 | 25.8 | 16.3 | 30.8 | 14.6 |
| Agave Hildana | 8000 | 30.6 | 21.8 | 13.6 | -- |
| Mlola 487 | 6400 | 20.1 | 20.0 | 19.4 | 19.2 |
| Mlola 487 | 8000 | 20.3 | 13.2 | 15.1 | 21.8 |

Samples from 3-Factor variety trial (Table 16) generally recorded relatively lower kappa number, between 13 and 17, where as Agave Sisalana 4000, Agave Hildana 6400 and 8400 and Mlola 8000 at plants/Ha recorded kappa number below 14. Agave Hildana 4000 had the highest kappa number.

**Table 16:** 3-Factor Variety Trial – kappa number

| **Variety** | **Density Plants/Ha** | **Kappa Number** |
|---|---|---|
| H.11648 | 4000 | 15.1 |
| H.11648 | 6400 | 14.6 |
| H.11648 | 8000 | 15.1 |
| Agave Sisalana | 4000 | 13.9 |
| Agave Sisalana | 6400 | 14.9 |
| Agave Sisalana | 8000 | 16.4 |
| Agave Hildana | 4000 | 16.9 |
| Agave Hildana | 6400 | 13.8 |
| Agave Hildana | 8000 | 13.7 |
| Mlola | 4000 | 15.0 |
| Mlola | 6400 | 15.1 |
| Mlola | 8000 | 12.6 |

III.8.2.4 Breaking Length

The CEPS I third harvest was observed to have extremely high breaking length (around 10 km) in relation to the other three harvests, which lies in a range of 5 to 7 km. With exception of H. 11648 at 6400 planting density, the lowest tensile strength in all varieties was observed in the fourth harvest. Generally no significant difference was observed on breaking length between the varieties, see Table 17 below.

**Table 17:** CEPS I trials – breaking length (km)

| Variety | Density Plants/Ha | Harvest | | | |
|---|---|---|---|---|---|
| | | First | Second | Third | Fourth |
| H. 11648 | 6400 | 4.5 | 6.7 | 10.0 | 5.3 |
| H. 11648 | 8000 | 7.2 | 6.2 | 11.8 | 6.6 |
| Agave Sisalana | 6400 | 5.8 | 8.2 | 11.0 | 5.1 |
| Agave Sisalana | 8000 | 6.9 | 6.6 | 12.1 | 5.8 |
| Agave Hildana | 6400 | 6.3 | 5.9 | 12.4 | 6.1 |
| Agave Hildana | 8000 | 6.2 | 7.3 | 10.2 | |
| Mlola | 6400 | 7.5 | 6.5 | 11.8 | 5.9 |
| Mlola | 8000 | 7.8 | 6.2 | 12.2 | 4.9 |

In the 3-Factor variety trials the breaking length was ranging between five and seven km, the average was about six km. H.11648 had almost constant breaking length around six km (see Table 18 below).

**Table 18:** 3-Factor variety trials – breaking length (km)

| Variety | Density plants/Ha | Breaking length (Km) |
|---|---|---|
| H. 11648 | 4000 | 5.9 |
| H.11648 | 6400 | 6.0 |
| H.11648 | 8000 | 6.0 |
| Agave Sisalana | 4000 | 5.6 |
| Agave Sisalana | 6400 | 5.3 |
| Agave Sisalana | 8000 | 5.3 |
| Agave Hildana | 4000 | 6.7 |
| Agave Hildana | 6400 | 6.3 |
| Agave Hildana | 8000 | 5.3 |
| Mlola | 4000 | 5.9 |
| Mlola | 6400 | 5.4 |
| Mlola | 8000 | 6.4 |

III.8.2.5 Tear strength

In CEPS I trials, generally the first and fourth harvests have shown higher tear strength and the lowest observed in the third harvest. In the 3-factor variety trial, generally Mlola recorded higher values in all densities and H.11648 recorded the lowest. The results obtained are included in Tables19 and 20.

**Table 19:** CEPS I trials – tear index ($Nm^2/g$)

| **Variety** | **Density plants/Ha** | **Harvest** | | | |
|---|---|---|---|---|---|
| | | First | Second | Third | Fourth |
| H. 11648 | 6400 | 18 | 15 | 14 | 21.0 |
| H. 11648 | 8000 | 27 | 15 | 14 | 27 |
| Agave Sisalana | 6400 | 21 | 22 | 22.0 | 14 |
| Agave Sisalana | 8000 | 22 | 24 | 13 | 26 |
| Agave Hildana | 6400 | 26 | 22 | 15 | 24 |
| Agave Hildana | 8000 | 13 | 31 | 12 | |
| Mlola | 6400 | 24 | 23 | 13 | 16.0 |
| Mlola | 8000 | 22 | 15 | 20 | 27 |

**Table 20:** 3-factor variety trials – tear index ($Nm^2/g$)

| **Variety** | **Density plants/Ha** | **Tear Index** $Nm^2/g$ |
|---|---|---|
| | | |
| H. 11648 | 4000 | 13.7 |
| H. 11648 | 6400 | 21.1 |
| H. 11648 | 8000 | 13.5 |
| Agave Sisalana | 4000 | 23.8 |
| Agave Sisalana | 6400 | 22.2 |
| Agave Sisalana | 8000 | 13.4 |
| Agave Hildana | 4000 | 26.9 |
| Agave Hildana | 6400 | 27.2 |
| Agave Hildana | 8000 | 14.4 |
| Mlola | 4000 | 23.8 |
| Mlola | 6400 | 32.1 |
| Mlola | 8000 | 26.2 |

III.8.2.6 Burst strength

Generally burst strength ranged between 2.5 and 4 $kPam^2/g$. In CEPS I the first and second harvests recorded higher burst strength than the third and fourth harvests. Highest values were observed in the second harvest of Mlola 8000, Agave Hildana 8000 and the first harvests of H.11648 and Mlola at planting density of 8000 plants/Ha. In the 3-factor variety trial, H.11648 and Mlola have shown an increase in burst strength with increasing density, while in Agave Sisalana and Agave Hildana the strength decreased with increasing planting density. Agave Hildana has however recorded the highest values in all densities. The results obtained are included in Tables 21 and 22.

**Table 21:** CEPS I trials – burst index ($kPam^2/g$)

| Variety | Density plants/Ha | Harvest | | | |
|---|---|---|---|---|---|
| | | First | Second | Third | Fourth |
| H. 11648 | 6400 | 2.7 | 3.4 | 3.1 | 3.2 |
| H. 11648 | 8000 | 4.8 | 2.6 | 3.3 | 3.3 |
| Agave Sisalana | 6400 | 3.7 | 4.0 | 3.0 | 2.9 |
| Agave Sisalana | 8000 | 3.9 | 3.8 | 2.8 | 3.8 |
| Agave Hildana | 6400 | 4.2 | 3.1 | 3.2 | 3.5 |
| Agave Hildana | 8000 | 3.3 | 4.9 | 2.7 | -- |
| Mlola | 6400 | 4.6 | 4.0 | 2.9 | 3.3 |
| Mlola | 8000 | 4.9 | 6.6 | 3.4 | 3.4 |

**Table 23:** Three-factor variety trials – burst index ($kPam^2/g$)

| Variety | Density plants/Ha | Burst Index ($kPam^2/g$) |
|---|---|---|
| H. 11648 | 4000 | 2.8 |
| H. 11648 | 6400 | 3.2 |
| H. 11648 | 8000 | 3.6 |
| Agave Sisalana | 4000 | 2.8 |
| Agave Sisalana | 6400 | 2.7 |
| Agave Sisalana | 8000 | 2.2 |
| Agave Hildana | 4000 | 4.2 |
| Agave Hildana | 6400 | 3.9 |
| Agave Hildana | 8000 | 4.0 |
| Mlola | 4000 | 2.5 |
| Mlola | 6400 | 3.5 |
| Mlola | 8000 | 3.7 |

III.8.2.7 Other results

As mentioned, samples from CEPS II leaves, UHDT leaves and from CEPS I bole fibre were pulped and the pulp analyzed. The results achieved are included in Table 24.

**Table 24:** Properties of pulp from CEPS II and UHDT leaves and from CEPS I bole

| **Trial** | **Density** (plants/ha) | **Harvest** | **Breaking length** (km) | **Tear index** ($Nm^2/g$) | **Burst index** ($KPam^2/g$) | **Kappa number** |
|---|---|---|---|---|---|---|
| CEPS IIA | 6,666 | 1st | 5.4 | 14.6 | 2.8 | 26.1 |
| CEPS IIA | 6,666 | 2nd | 5.1 | 27.7 | 3.1 | 23.3 |
| CEPS IIB | 6,666 | 1st | 5.0 | 11.9 | 2.8 | 19.5 |
| CEPS IIB | 6,666 | 2nd | 5.7 | 18.6 | 3.1 | 12.0 |
| UHDT | 12,500 | 1st | 4.9 | 18.0 | 4.3 | 33.7 |
| UHDT | 12,500 | 2nd | 6.3 | 16.4 | 3.2 | 15.6 |
| UHDT | 12,500 | 3rd | 6.0 | 19.3 | 3.4 | 24.7 |
| UHDT | 16,666 | 1st | 4.0 | 11.0 | 1.9 | 38.2 |
| UHDT | 16,666 | 2nd | 4.9 | 9.8 | 2.9 | 10.2 |
| UHDT | 16,666 | 3rd | 4.6 | 13.5 | 3.1 | 17.1 |
| UHDT | 25,000 | 1st | 4.5 | 16.7 | 3.0 | 34.3 |
| UHDT | 25,000 | 2nd | 5.7 | 16.4 | 3.1 | 26.7 |
| UHDT | 25,000 | 3rd | 5.8 | 12.9 | 3.5 | 26.5 |
| UHDT | 33,333 | 1st | 4.3 | 12.9 | 1.7 | 28.2 |
| UHDT | 33,333 | 2nd | 5.9 | 20.6 | 3.9 | 27.3 |
| UHDT | 33,333 | 3rd | 5.4 | 20.5 | 3.5 | 32.9 |
| CEPS I Bole H. 11648 | 6400 | 4th | 2.6 | 6.2 | 1.2 | 14.8 |
| CEPS I Bole Agave Hildana | 6400 | 4th | 2.7 | 7.3 | 1.5 | 14.7 |
| CEPS I Bole Mlola | 8000 | 3rd | 2.5 | 5.7 | 1.1 | 33.9 |
| CEPS I Bole Mlola | 8000 | 4th | 1.8 | 2.9 | 0.7 | 35.9 |

*Note: Variety used in CEPS II and UHDT is H. 11648*

From the results obtained, it could be inferred that, generally, bole pulp recorded low tensile, tear and burst strength. Pulping conditions for boles were too different from pulping conditions for leaves, therefore it was not advisable to mix fibre from the two sources and the original idea of "whole plant" harvesting had to be disregarded. Nevertheless the possibility of extracting fibre from boles separately and selling the fibre should be considered.

## III.9 The feasibility analysis study for a FEX plant

The report prepared by Katani Ltd., with the assistance from UNIDO, is included as Annex 8.

The main objectives of the project will be:

- To cultivate 2,400 hectares of sisal under intensive CEPS systems starting in 2006 with 510 hectares and thereafter 210 hectares each year to be able to get sisal leaves under selective leaf harvesting leaving not less than 20 leaves per plant each time it is cut. The first cut will be after 24 months.
- To produce seven tonnes per shift (one seven-hour shift) or 5,670 tonnes of staple sisal fibre for 270 days per annum when three shifts are operated. This will be reached from year 2013.
- To generate revenue of US$ 3,561,600 from staple fiber annually by year 2015.

Three oxidation ponds are provided in the project to treat 315 $m^3$ of wastewater per day from the extraction process to reduce environmental damage. After treatment, the solid dried product will be used as fertilizer on the estate and the water for irrigation of the nurseries.

The project will use the results from the smallholder/outgrower scheme, the CEPS trials and the new FEX technology with two hammer mills in parallel for first pass and a third in series for the second and last pass. The projected fibre yield averages 4.1% of fresh leaves by weight. Technical staff required will be recruited mostly from personnel involved in the pilot phase of the project. Katani Limited has set aside more than 2,400 hectares for sisal growing under CEPS mode using smallholders/outgrowers for the FEX plant at Mruazi section of Hale Estate.

Two scenarios were considered: one with three hammer mills and one with two hammer mills.

Project financing for the three-hammer mill scenario is proposed to be through equity, grants and loans. From Katani Limited equity of US$ 613,737 in cash (US$ 213,737) and in kind (US$ 400,000) is expected. From CFC it is suggested to have a grant of US$ 401,195 for the pilot hammer mill system and the second hammer mill for optimization of the process. Also CFC will be requested to provide a soft loan of US$ 976,750 (excluding capitalized interest) to be disbursed in 2006 and 2007. Retained earnings could be used to finance the balance. A grace period of three years and five years repayment at an interest rate of 4% per annum charged on the outstanding balance are assumed for the loan.

The project duration is 11 years. The total investment cost for the three-hammer mill scenario is estimated to be US$ 3,249,300 (excluding capitalized interest). Working capital requirements are estimated at US$ 360,479. Normal payback period before discounting is eight years. The dynamic payback period to total capital invested after discounting is 10 years. The IRR to total capital invested is 19.13% while IRR to equity is 34.82%.

Project financing for the two-hammer mill scenario will similarly be through equity, grants and loans. Katani Limited will provide equity of US$ 301,525 in cash (US$ 151,525) and in kind (US$ 150,000). CFC will provide a grant of US$ 401,195 and a soft loan of US$ 595,930 (excluding capitalized interest), to be disbursed in 2006 and 2007. Retained earnings will finance the balance. A grace period of three years and five years repayment at an interest rate of 4% per annum charged on the outstanding balance is assumed for the loan.

The project duration for the two-hammer mill scenario is similar and total investment cost will amount to US$ 2,033,668 (excluding capitalized interest.) Working capital requirements are estimated at US$ 183,255. Normal payback period before discounting is nine years. The dynamic payback period to total capital invested after discounting is 12 years. The IRR to total capital invested is 13.59% while IRR to equity is 35.1%.

Operation of the hammer mill from May 2004 to September 2004 revealed that certain parameters required extended period of operation with all sub-systems in place to reduce the risks. The project plans to confirm key production parameters after operating a pilot plant with two hammer mills in 2005 for some time. The first hammer mill will be used for the first pass of the chips and the second (new) hammer mill for the second pass. A feeding system for the first hammer mill, collector and discharge conveyors for the second hammer mill will be provided to enable the system to operate continuously. There is a market for sisal fiber in the specialty pulp market, which the project will exploit.

## III.10 Chemical analysis of sisal waste

The sample collection was done on 23 February 2005 at Kwaraguru and Hale Estates. Samples collected include effluents from decortications and flume tow recovery system at Kwaraguru, hammer mill effluent and sisal leaf juice at Hale Estate. About two liters of each sample were collected and buried under ice chips in the iceboxes immediately after their collection. Samples were then transported to the Chemistry Department laboratories at the University of Dar es Salaam where they were stored in the fridges awaiting further analysis.

Measurements for some parameters such as temperature and pH were performed immediately (on site) on each sample at the collection time. Analysis for some parameters was performed the following day, and other parameters were completed two weeks after their collection at the Chemistry Department laboratories. Analysis performed includes determinations for metals, anions and measurements of physical chemical parameters.

The results achieved are included in Annex 6.

On the bases of the results obtained the following comments can be made:

- Sisal leaf juice (fresh) sample showed ample quantities of total organic acid, total organic carbon, sugars and amino acids. Effluent samples showed low values of the same substances, the highest being sugars followed by total organic acid, total organic carbon and amino acids.

- Sugar content: This parameter was quite significant across the effluent samples. It is a parameter of economic value as it can be utilized in the production of alcohol, animal feeds, etc.
- Total organic acids: Ample amount of total organic acids was found in all effluent samples. This could be of economic value depending on the type of the acid present and more in-depth analyses are needed to assess the type of acids. These cannot be performed by the University of Dar es Salaam.
- Amino acids: This parameter is also significant across the effluent samples. It could be a parameter of economic value; it can be utilized as animal feeds and related uses.

# IV. Lessons Learned

## IV.1 Technology selection for FEX plant

From the experience gained it can be concluded that:

- The roller crusher did not perform as the one used in the Netherlands because the diamond shape of the roller surface pattern was not achieved; roller crushing is not advisable as the process causes fibre damaging which results in low pulp yield.
- It is not recommended even to combine the roller crusher with the present design of the hammer mill, as it confers no advantage. This is due to the fact that the upper hammers of the hammer mill do the preliminary crushing. The lower hammers do the crushing and parenchyma separation in the hammer mill. The effect in the lower hammers is the same whether the chips are crushed prior to feeding to the hammer mill or not.
- It is not recommended to use water bath washing systems as they require large quantities of water, and separation of mucilage was not clearly confirmed. The flow of parenchyma is facilitated by water; therefore it is important to introduce water inside the hammer mill to attain better quality of the fibre.
- It is recommended to operate two hammer mills in parallel to do the first pass with water injected inside each hammer mill, and one hammer mill in series to do the second pass with water injected before the hammer mill and inside the hammer mill.
- The fibre produced had moisture content of about 71%, which would require squeezing to reduce moisture before it is sent to the drier. After squeezing, two carding units will be required, one before the drier to loosen the fibre to facilitate drying and another one after the drier to brush the fibre to reduce parenchyma content from 5% to about 3%. Industrial drying mechanisms should be further evaluated.

## IV.2 Main characteristics of sisal pulp

From the results achieved in the pulping trials, it can be concluded that:

- Visual appearance of uncooked fibre: the fibre extracted using the roller crusher was damaged. The damaged, soft fibre obtained from the roller crusher (three-factor trial samples) has faster delignification during cooking. This is indicated by the lower kappa number of three-factor trial samples, than undamaged fibre from the hammer mill (e.g., CEPS I, fourth harvest).
- Visual appearance of pulp: the amount of shives in pulp samples from the hammer mill indicated a low level of delignification, probably due to less effect of chemicals due to the presence of a high percentage of residual parenchyma and omission of the use of Anthraquinone. Anthraquinone was originally included in the TOR, but Katani Ltd. did not use it due to lack of facilities to weight the product. Samples from the roller crusher showed low shives content probably due to over crushing, which acted more or less as an initial stage of mechanical pulping.
- Pulp yield: the drop in pulp yield at the third harvest of CEPS I may have been be caused by the fibre extraction method used (roller crusher). The fourth harvest was extracted using the hammer mill, which produced

undamaged fibre resulting in high yield. There were no significant differences in pulp yield between different varieties.

- Kappa number: the high kappa number of all the samples may have been caused by the high percentage of residual parenchyma. Fibre from hammer mill and roller crusher was found to have 8 to 10% residual parenchyma thus requiring more chemicals in delignification. If used, Anthraquinone would have acted as catalyst during delignification. Although the parenchyma contents were in the same range, fibre from 3-factor trials and extracted by roller crusher produced pulp with relatively low kappa number compared with pulps from hammer mill fibre probably, as mentioned above, due to excessive crushing and cutting caused by the rollers facilitating the penetration of the pulping chemicals in the fibre.
- Breaking length: fibre from the fourth harvest had a relatively high degree of polymerization of the lignin chain, requiring stronger cooking conditions to remove the larger amount of lignin which is more prevalent in older sisal than in younger sisal. In general, tensile strength of pulps from the fourth harvest were lower indicating hard pulp and resulting in low pulp tensile strength, expressed as breaking length. The third harvest was processed using the roller crusher. Due to excessive crushing the fibre is subjected to partly mechanical pulping, making it easy for chemicals to penetrate through the fibre producing soft and flexible pulp. As a result more collapsed individual pulp fibre is obtained during refining and more external bonds are formed, thus generating a higher tensile strength.
- Tear strength: this characteristic depends on the external pulp fibre bonds as well as of the strength of the individual fibre walls. The cellulose fibre from the first harvest appears to be flexible and can cause entangling between, resulting in high tear strength. In the fourth harvest, the fibres have shown high tear strength, probably due to the higher strength of the individual fibre walls.
- Burst strength: the burst strengths of the pulps obtained from the third and fourth harvests are in general low but present less variation between samples than the values observed for the first and second harvests. The 3-factor trials results indicate that the effect of the plant density is positive for the varieties H. 11648 and Mlola, negative for *Agave Sisalana* and practically none for *Agave Hildana.* This last variety presents the highest values.
- Bole fibre and leaf fibre cannot be mixed, as the pulping conditions and the quality of the pulp obtained are very different.

## IV.3 The feasibility analysis study for a FEX plant

It is recommend by Katani Ltd. that the three-hammer mill scenario be adopted and implemented as it is, within the original appraisal loan amount. Despite the fact that both scenarios have an IRR higher than the discount rate used in the financial analysis, the results indicate that the scenario with three hammer mills is the more profitable one.

## IV.4 Development lessons

The activities implemented met the overall sub-component objectives. In particular technologies for the extraction of sisal fibre suitable for pulping at competitive costs were evaluated and the results used to propose the layout of a FEX plant. The trials conducted confirmed that hammer milling is the most suitable technique to produce fibre for pulp and paper applications and proved that two passes in the hammer mill are needed to reduce parenchyma to the satisfactory level of less than 5%.

The results achieved and the information collected allowed the preparation of a feasibility analysis study for a FEX plant. Nevertheless Katani Ltd. found that the data available is insufficient and inadequate for the production of a bankable document. This is because the prototype hammer mill was designed to benchmark alternative technologies for fibre extraction and not to perform industrial operations, therefore the system allows only for batch runs and single passes.

During the Project Coordinating Committee Meeting held in November 2004, it was recommended that the project sub-component be further funded. The Food and Agriculture Organization (FAO) Intergovernmental Group on Hard Fibres endorsed the proposal, in principle (17 December 2004), and a new "fast-track" project ("Operationalization of a pilot facility for a continuous sisal fibre extraction /production process") was funded by CFC.

The new activities to be carried out include: the construction, erection, and testing of a second hammer mill in series with the existing one and of an upgraded washing system at the existing experimental hammer mill site, the system operation and the preparation of a new feasibility study for a FEX plant, which will take into consideration the new parameters and the data collected.

Altogether the pulping tests can be considered as successful, even though clear indications of the performance of different varieties, densities and harvesting periods cannot be drawn. Yet Hybrid 11648 was probably the best variety. An important finding of the sub-component is certainly the evidence that boles and leaves cannot be pulped together because of the different pulping conditions required and the different quality of the pulp. As a consequence the initial idea of whole plant harvesting had to be disregarded. The characteristics of sisal pulp were investigated further as part of sub-component C.2 "Pulp Pilot Production". Despite the specifications included in the Terms of Reference Anthraquinone was not used due to difficulties in weighing.

## IV.5 Operational lessons

- Despite the many delays experienced, partly due to the fact that the equipment developed was a prototype and partly to the fact that the activities conducted were experimental, the implementation arrangements proved to be adequate.
- TATC proved to be a satisfactory contractor; despite some delivery delays the activities were carried out professionally and met the specifications included in the Terms of Reference.
- The implementation of pulping and selection of technology activities suffered from the unfortunate loss of one member of the national project staff.

# V. Conclusions and Recommendations

- Sisal fibre produced using hammer mill and roller crusher have a high percentage of residual parenchyma, about 10% by weight, which affects the pulp characteristics. The white amorphous parenchyma adhering to the fibre cannot be removed by further washing. Fibre extraction technology selection should take into account these observations to ensure the production of fibre of commercial grade with residual parenchyma around 3% to attain high strength and low kappa number.

- It is recommended to use the hammer mill for fibre extraction due to its extraction efficiency. Roller crusher causes fibre damaging which results in low pulp yield.

- Total plant harvesting has been shelved due to difference in leaf and bole fibre characteristics. Selective harvesting over a number of years until sisal stops producing leaves has been adopted. This means harvesting will continue beyond the fourth harvest.

- Hybrid 11648 was generally found to be superior in terms of tensile and tear strength and bleachability, due to its low kappa number especially at the planting density of 6400 plants per hectare.

- The hammer mill could be operated continuously for only 15 minutes while it is necessary to perform two passes and to run the mill continuously at full load for one shift/day of about eight hours and over a longer period (from one to two months) to confirm reliability of the equipment and establish wear and tear of running parts, power consumption, water consumption and labour requirements. This information is needed to enable the project counterpart to submit a bankable feasibility analysis for a fibre extraction plant to access the CFC loan.

- Considering the results of the feasibility analysis study for a FEX plant, it is advisable to consider the 3-hammer mill scenario, as it is more profitable. Investment and production costs, derived from the A.3, C.1 and C.2 activities, are specified in the feasibility analysis study (Annex 8).

# Annex 1. Design of prototype hammer mill, feeder and conveyors: List of drawings

**Set 1 – Vertical mill manufacturing drawings and English translations (include lay out of the complete plant)**

| Drawing No. | Title | Subtitle |
|---|---|---|
| 001 | Sisal defibering plant | Equipment layout |
| ES-001 | Vertical mill | Base structure for the vertical mill |
| MV-001A | Vertical mill | Vertical mill set A-A cut |
| MV-001B | Vertical mill | Vertical mill upper view |
| MV-002 | Vertical mill | Table set |
| MV-003 | Vertical mill | Table details |
| MV-004 | Vertical mill | Supporting ground plate – details 1 |
| MV-005 | Vertical mill | Supporting ground plate – details 2 |
| MV-005/1 | Vertical mill | Supporting ground plate – details 2 – Rev. 1 |
| MV-006 | Vertical mill | Bearing set and details |
| MV-007 | Vertical mill | Bearing details |
| MV-008 | Vertical mill | Pulley details and bearing lids |
| MV-008/1 | Vertical mill | Pulley details and bearing lids – Rev. 1 |
| MV-009 | Vertical mill | Set of rotors |
| MV-010 | Vertical mill | Rotor and hammer details |
| MV-011 | Vertical mill | Screen details |
| MV-012 | Vertical mill | Motor structure set and details |
| MV-013 | Vertical mill | Motor structure and details |
| MV-014 | Vertical mill | Screen flanges, discharge spout |
| MV-015 | Vertical mill | Scrapper drive set |
| MV-015/1 | Vertical mill | Scrapper drive set – Rev. 1 |
| MV-016 | Vertical mill | Details: crown, pinion, supporting ring |
| MV-017 | Vertical mill | Scrapper set and details |
| MV-018 | Vertical mill | Lid set and details |
| MV-019 | Vertical mill | Screen outer cover set and details |
| MV-020 | Vertical mill | Sub-set and details of screen outer cover |
| MV-021 | Vertical mill | Protection of the belts |

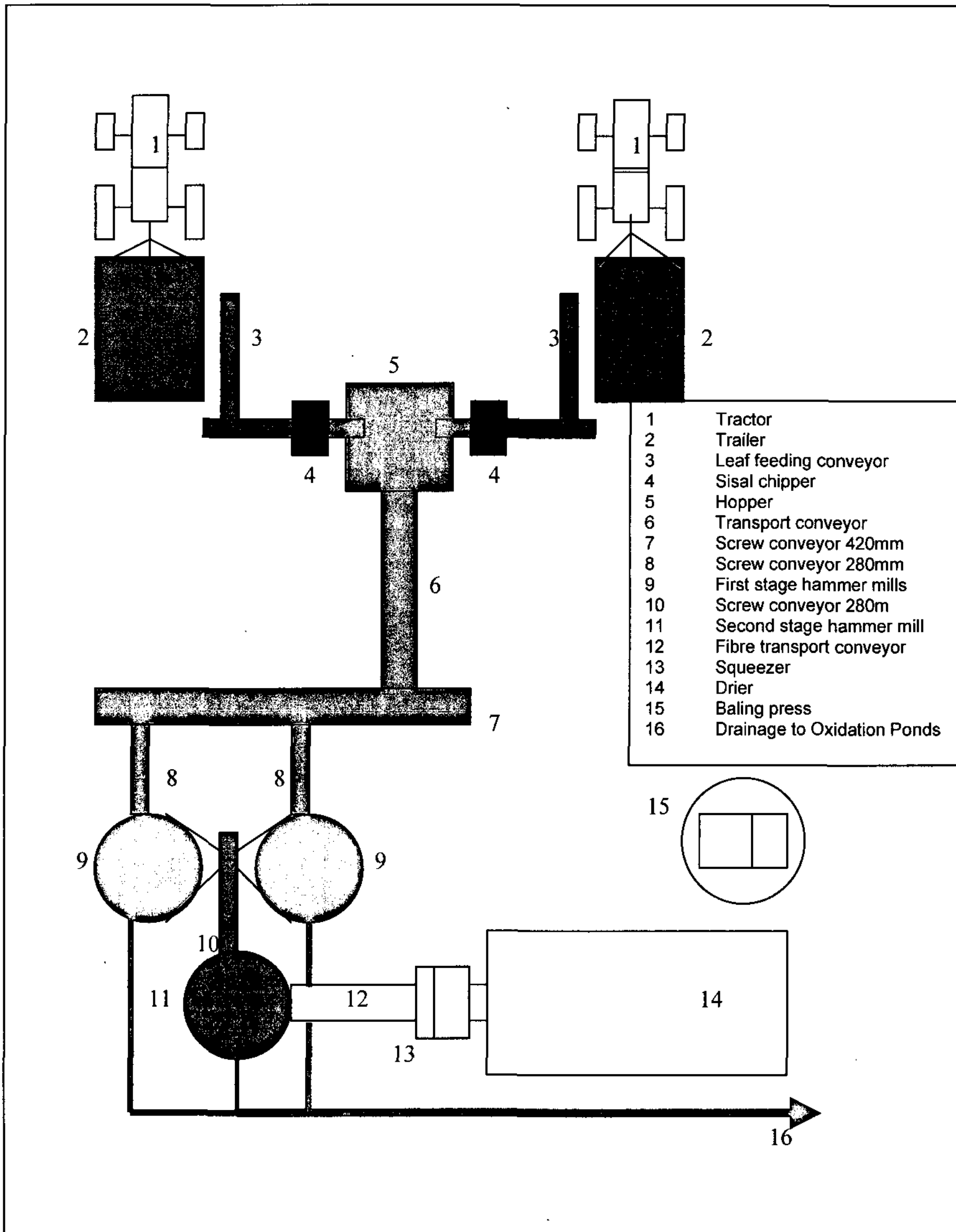
**Set 2. Rotating dosing feeder manufacturing drawings and English translation**

| Drawing No. | Title | Subtitle |
|---|---|---|
| AR-001 | Rotating dosing feeder | Set |
| AR-002 | Rotating dosing feeder | Structure |
| AR-003 | Rotating dosing feeder | Details |
| AR-004 | Rotating dosing feeder | Rotor set details |
| AR-005 | Rotating dosing feeder | Base for motor – reducer drive and details |
| AR-006 | Rotating dosing feeder | Drive assembly – Rev. 1 |

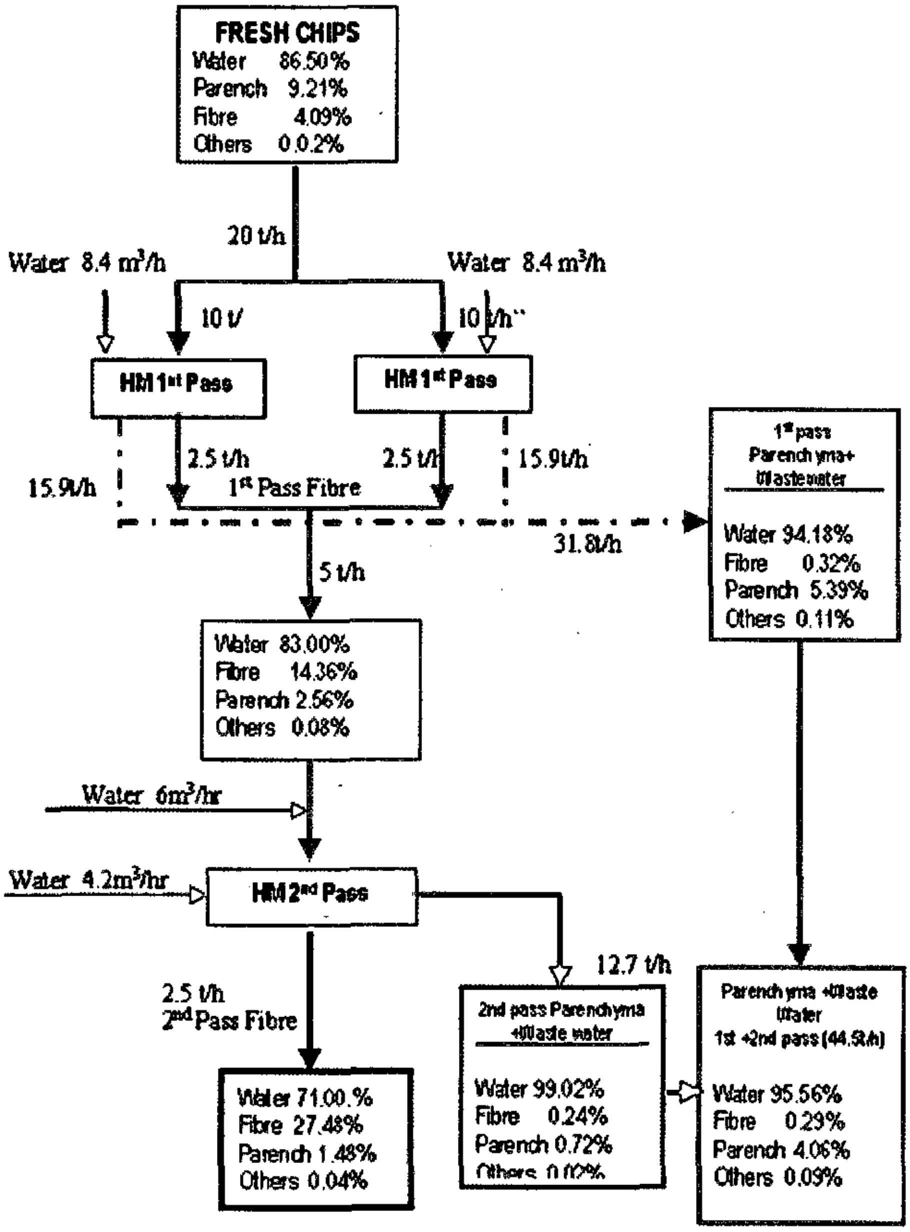
**Set 3. Helicoidal conveyors manufacturing and English translation**

| Drawing No. | Title | Subtitle |
|---|---|---|
| TH-001 | Helicoidal conveyor | Set screw Ø 420 mm |
| TH-002 | Helicoidal conveyor | Screw details |
| TH-003 | Helicoidal conveyor | Casing seat and details |
| TH-004 | Helicoidal conveyor | Distribution chute |
| TH-005 | Helicoidal conveyor | Set screw Ø 280 mm |
| TH-006 | Helicoidal conveyor | Chute set and details |
| TH-007 | Helicoidal conveyor | Chute and details |
| TH-008 | Helicoidal conveyor | Screw and details |
| TH-009 | Helicoidal conveyor Ø 420 mm | Drive details |
| TH-010 | Helicoidal conveyor | Drive assembly thread Ø 420 mm |
| TH-011 | Helicoidal conveyor Ø 280 mm | Base for reducer |
| TH-012 | Helicoidal conveyor | Drive assembly thread Ø 280 mm |

# Annex 2. Preliminary layout for FEX plant

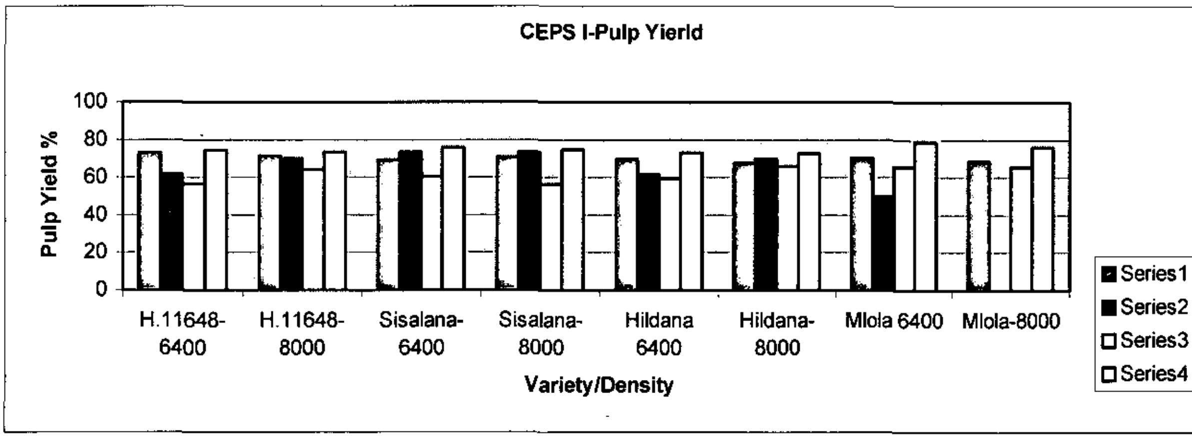


# Annex 3. Preliminary mass balance for FEX plant

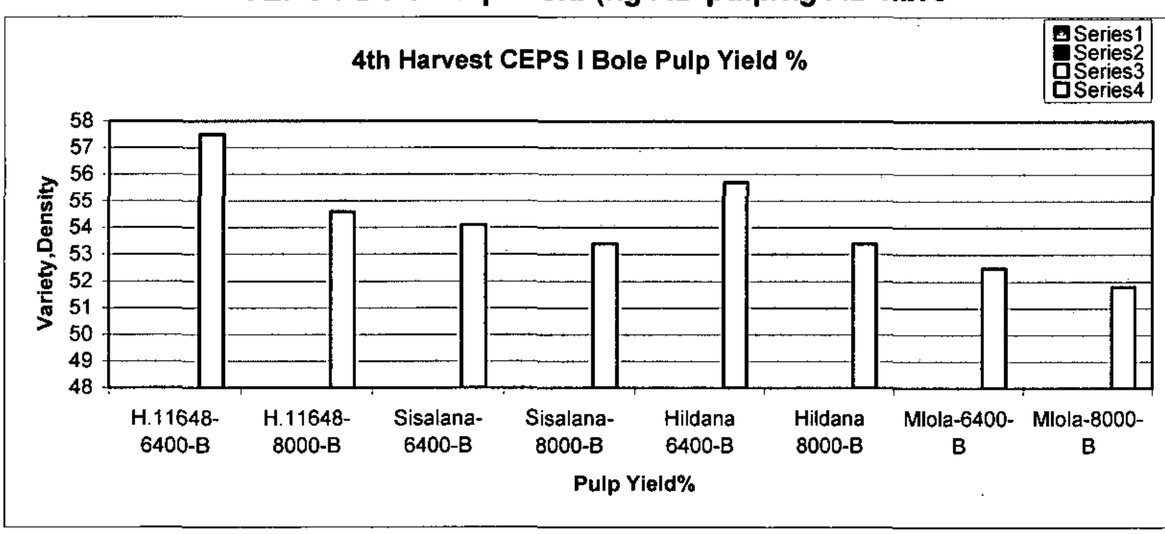


# Annex 4. Pulping and pulp evaluation

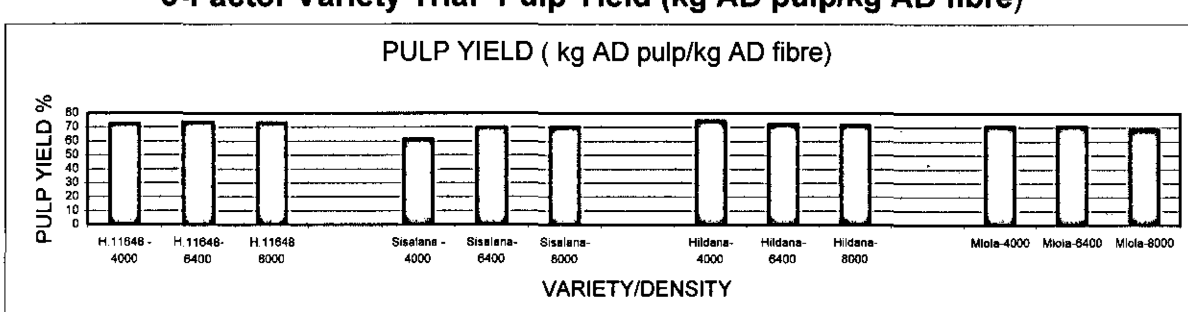
## CEPS I- Leaf Pulp Yield (kg AD pulp/kg AD fibre)



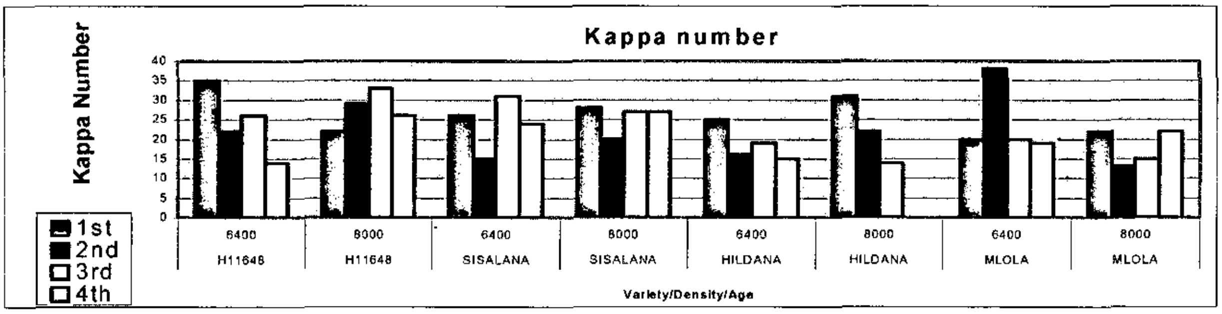

## CEPS I-Bole Pulp Yield (kg AD pulp/kg AD fibre



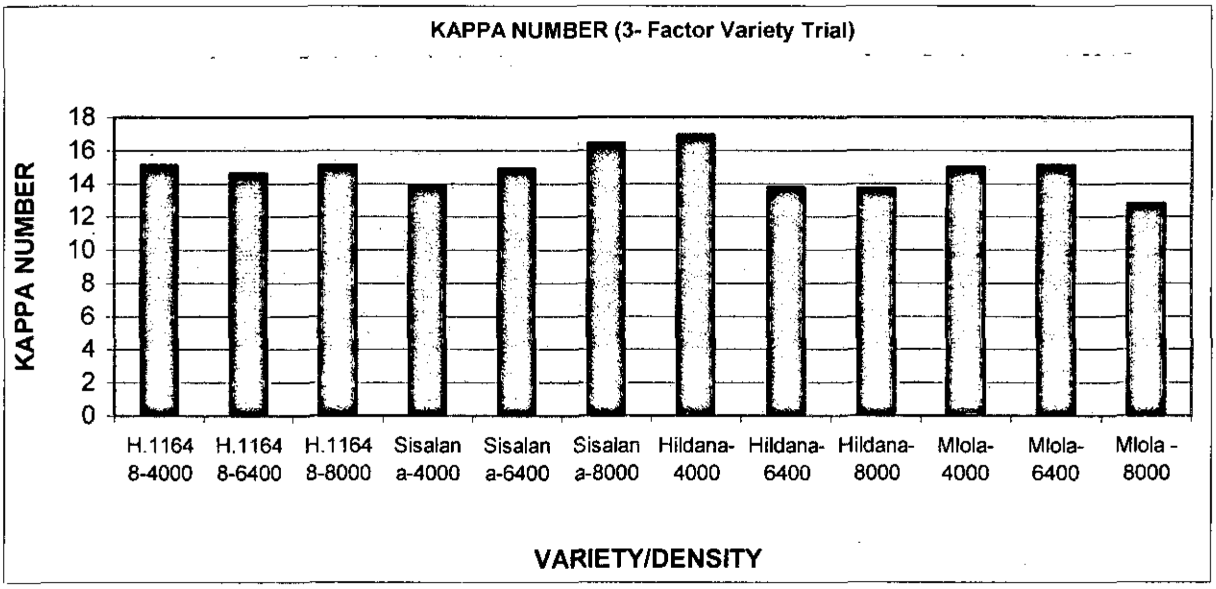

## 3-Factor Variety Trial- Pulp Yield (kg AD pulp/kg AD fibre)



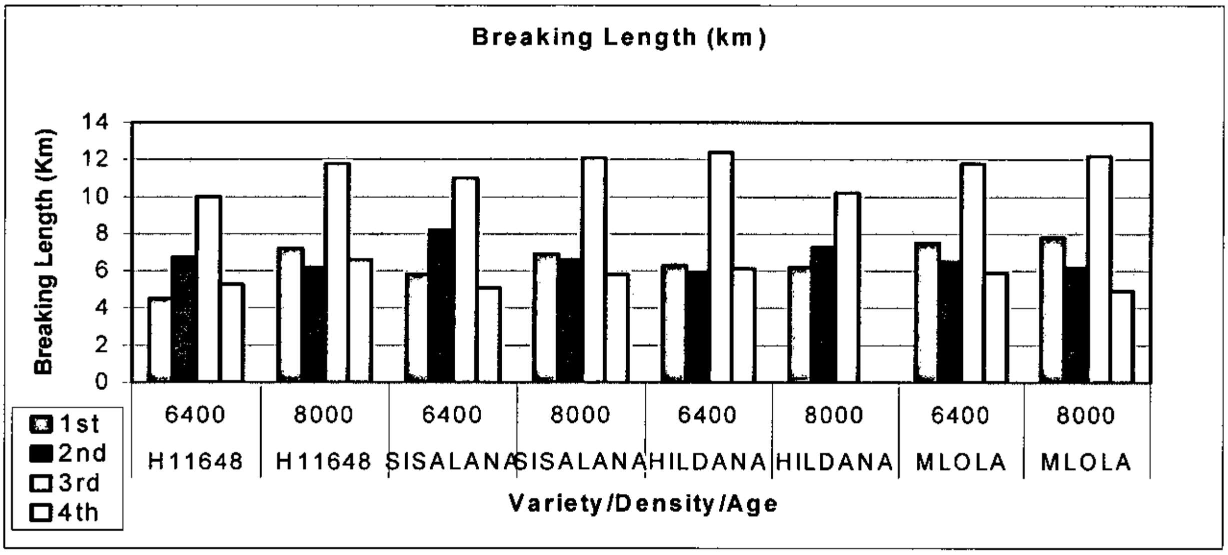
## CEPS I- Kappa Number



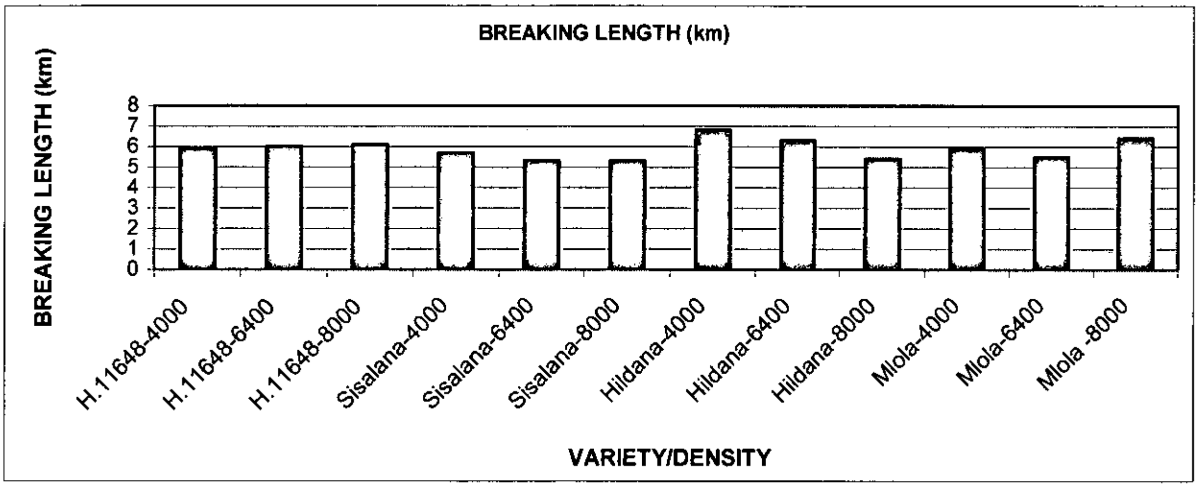

## 3-Factor Variety Trial- Kappa Number



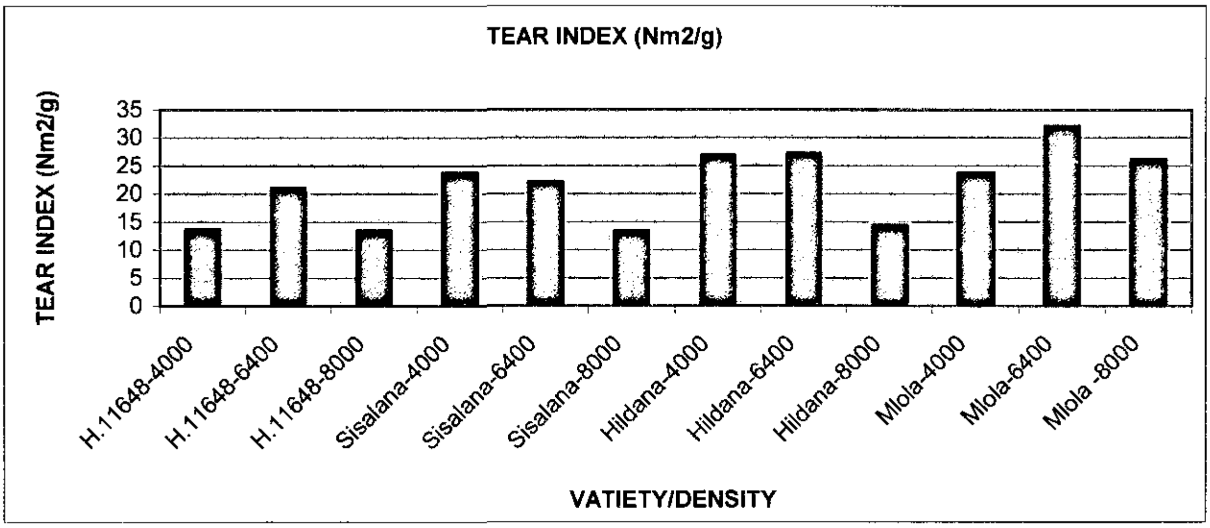
**CEPS I - Breaking Length (km)**



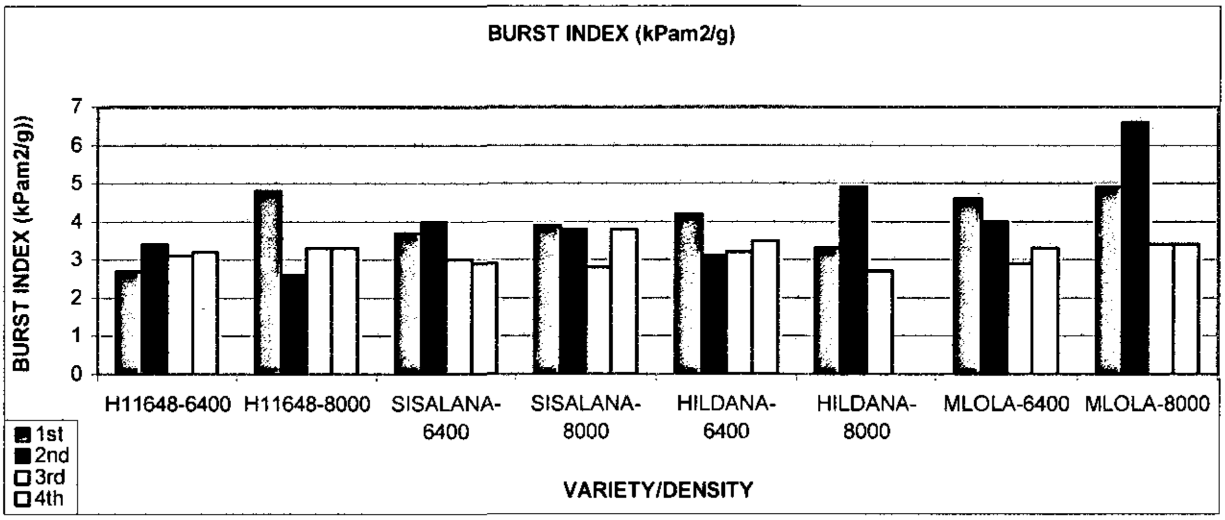

## 3-Factor Variety Trial - Breaking Length (km)



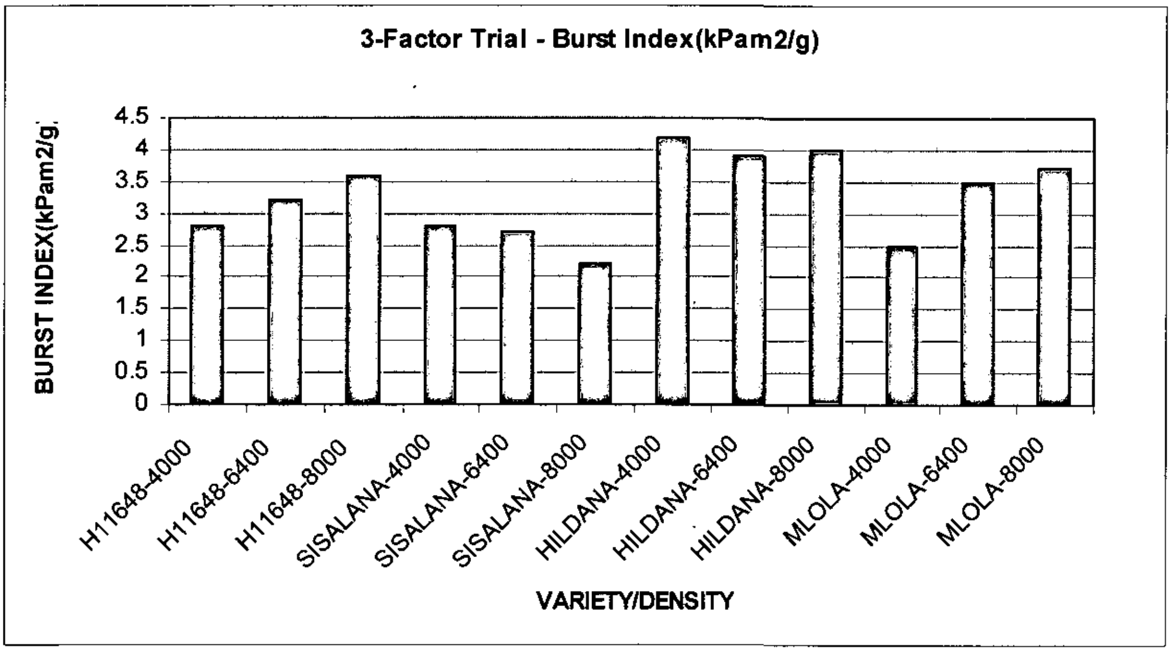
## 3-Factor Variety Trial – Tear Index (Nm$^2$ /g)




## CEPS I – Burst Index (kPam$^2$ /g)



## 3-Factor Variety Trial – Burst Index (kPa$m^2$/g)



# Annex 5. Pulp testing methods

TAPPI testing procedures were adopted and the description of the processes is as follows:

1.1 Kappa number.

1.1.1 Definition:

The kappa number is the volume in milliliters of 0.1 N potassium permanganate solution consumed by one gram of moisture free pulp under the conditions specified in this method. The results are corrected to 50% consumption of the permanganate.

1.1.2 Apparatus for measuring kappa number:

- Agitator, propeller type, made of non-corrosive material such as glass.
- Disintegration apparatus, of wet, high-speed type, which disintegrates the pulp completely with a minimum damage to the fibers.
- Constant temperature bath, capable of maintaining a constant temperature of 25 $^0$C in the reaction vessel.
- Reaction beaker, 2000-ml, glass.
- Pipettes, two 100-ml automatic pipettes.
- Burette, 50-ml, graduated to 0.1 ml.
- Other apparatus: a Buchner funnel and filter flask to dewater three to four grams of pulp; stop watch or clock; 1000-ml and a 50-ml graduated cylinder; 250-ml beaker.

1.1.3 Reagents for kappa number:

- Potassium permanganate solution, standardized 0.1 N $KMnO_4$.
- Sodium thiosulphate solution, approximately 0.2N $Na_2S_2O_3$.
- Potassium iodide solution, 1.0N K.I
- Sulphuric acid, 4N $H_2SO_4$.
- Starch indicator solution, 0.2%.

1.1.4 Preparation of sample for measuring kappa number:

- Air-dried pulp sheets. Tear small pieces from the sample sheets to weigh a total of three to four grams.
- Screened slush sheets. Mix and make three to four grams (dry weight) into a pad by filtering on a Buchner funnel. Air-dry the pad and tear it into small pieces.
- Unscreened pulps. If the pulp sample is taken from unscreened pulp, which is normally screened before bleaching and other processing, then remove the under-cooked fiber and knots from the sample by screening.

1.1.5 Procedure for measuring kappa number:

- Prior to weighing the test samples, condition them for at least 20 minutes in the atmosphere near the balance.
- Weigh out to the nearest 0.001 g that amount of pulp specimen, which will consume approximately 50% of the potassium permanganate solution. The permanganate consumption must be between 30 and 70%. At the same time weigh out a second specimen and determine its moisture content.
- Disintegrate the test specimen in 500 ml or less of distilled water until free of fiber clots and un-dispersed fiber bundles.
- Transfer the disintegrated test specimen to a 2000-ml reaction beaker and rinse out the apparatus with enough distilled water to bring the total volume to 795 ml.
- Place the beaker in a constant temperature bath adjusted so that the reaction temperature stays at 25 $^0$C during the entire reaction. Continuously stir the suspension so as to produce a vortex about 25 mm deep but not so fast as to introduce air into the mixture.
- Pipette 100 ml of potassium permanganate solution and 100 ml of the sulfuric acid solution into a 250-ml beaker. Bring this mixture to 25 $^0$C quickly and add it immediately to the disintegrated test specimen, simultaneously starting the stopwatch. Rinse out the beaker, using not more than 5 ml of distilled water, and add the washings to the reaction mixture. The total volume should be 1000 $^+$/. 5 ml.
- At the end of exactly 10 minutes, stop the reaction by adding 20 ml of the potassium iodide solution from a graduated cylinder.
- Immediately after mixing, but without filtering out the fibers titrate the free iodine with the sodium thiosulfate solution, adding a few drops of the starch indicator toward the end of the reaction.
- Carry out a blank determination using exactly the same method as above but omitting the pulp.

1.1.6 Calculations for kappa number:

Calculate the kappa number as follows:

$$K = p \times f/w \quad (2)$$

and

$$p = (b - a)N/0.1 \quad (3)$$

Where K is the kappa number,

f is the factor for correction to a 50% permanganate consumption, dependent on the value of p.

w is the weight of moisture-free pulp in the specimen in grams.

p is the amount of 0.1N $KMnO_4$ actually consumed by the test specimen in ml.

b is the amount of $Na_2S_2O_3$ consumed in the blank determination in ml.

a is the amount of $Na_2S_2O_3$ consumed by the test specimen in ml.

N is the normality of the $Na_2S_2O_3$.

**F Values for kappa number:**

| F | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 30 | 0.958 | 0.960 | 0.962 | 0.964 | 0.966 | 0.968 | 0.970 | 0.973 | 0.975 | 0.977 |
| 40 | 0.979 | 0.981 | 0.983 | 0.985 | 0.987 | 0.989 | 0.991 | 0.994 | 0.996 | 0.998 |
| 50 | 1.000 | 1.002 | 1.004 | 1.006 | 1.009 | 1.011 | 1.013 | 1.015 | 1.017 | 1.019 |
| 60 | 1.022 | 1.024 | 1.026 | 1.028 | 1.030 | 1.033 | 1.035 | 1.037 | 1.039 | 1.042 |
| 70 | 1.044 | | | | | | | | | |

1.2 Tensile properties.

1.2.1 Definitions:

These definitions are in accordance to ISO 1924.

- Tensile strength: The maximum tensile force per unit width that paper or board will withstand before breaking under the conditions defined in the standard test method.
- Breaking length: The calculated limiting length of a strip of paper or board of any uniform width, beyond which, if such a strip were suspended by one end, it would break under its own weight.

1.2.2 Principle for tensile properties:

A test piece of given dimensions is stretched to rupture at a constant rate of loading using a tensile testing apparatus that measures tensile force. The maximum tensile force is recorded. From the results obtained and knowledge of the basis weight of the sample, the breaking length is calculated.

1.2.3 Procedure.

Set up the apparatus as recommended by the manufacturer. Position the clamps so that the test length (the distance between the closest points at which the test piece is firmly gripped) is 180 mm. Verify that the test length is correct by measuring the distance between the two impressions produced by the clamps when clamping the strips of thin aluminum foil.

1.2.4 Determination:

Unless otherwise specified, carry out the operations involved in the measurement of the tensile strength of each test piece in the manner recommended by the manufacturer of the apparatus in use. Verify the zero position of the measuring device. Adjust the clamps to the required test length and place the test piece in the clamps ensuring that the fingers do not touch the test area between the clamps. Align and tightly clamp the test piece so that any observable slack is eliminated but the test piece is not placed under any significant strain. Ensure that the test piece is clamped in such a manner that its edges are parallel to the direction of application of the tensile force. By an initial trial experiment, select a rate of application of tensile force, which causes the test piece to fail in a mean time of 20 s. Record the maximum tensile force exerted and the time taken to rupture to the nearest second.

1.2.5 Calculations:

- Tensile strength:

  Calculate the tensile strength of the test pieces, expressed in kilo-Newton per meter, from the equation,

  $$S = F_T/w \qquad (4)$$

Where $S$ is the tensile strength, in kilo-Newton per meter.
$F_T$ is the mean tensile force in Newton.
$w$ is the width of the test piece, in millimeters.

- Breaking length.

  The breaking length $l_B$ expressed in kilometers, is calculated from the equation,

  $$l_B = F_T \times 10^3 / 9.81 \times w \times g \qquad (5)$$

Where g is the basis weight of the hand sheet in grams per square meter.

1.3 Determination of tearing resistance (Elmendorf method):

1.3.1 Definitions:

- Tearing resistance: The mean force required to continue the tearing started by an initial cut in a single sheet of paper (or board). If the initial cut is in the machine direction, the result is given as machine direction tearing resistance; similarly, if the initial cut is in the cross direction, the result is given as cross direction tearing resistance. The result is expressed in mill-Newton (mN).
- Tear index: The tearing resistance of the paper (or board) divided by its basis weight gives the tearing index. The result is expressed in mill-Newton square meters per gram ($mN.m^2/g$).

1.3.2 Principle:

A test piece of superimposed sheets (normally four), with a specified pre-cut slit, is torn through a fixed distance using a pendulum which applies the tearing force by moving in a plane perpendicular to the initial plane of the test piece. The work done in tearing the test piece is measured by the loss in potential energy of the pendulum. The average tearing force (work done divided by the total distance torn) is indicated on the scale of the pendulum or a digital display. The tearing resistance of the paper is determined from the average tearing force and the number of sheets comprising the test piece.

1.3.3 Procedure:

Carry out the tests in the same conditioning atmosphere used to condition the samples. Carry out a few tests by the procedure below in order to select the appropriate pendulum or pendulum/augmenting mass combination. It is desirable to arrange for the mean readings to fall within the range 20% to 80% of the full-scale reading, although values based on readings taken outside these limits may be noted in the report. Raise the pendulum to its initial position and secure it by the pendulum release mechanism. Carefully position the test piece in the clamps so that the slit, if pre-made, is centrally situated between the clamp on the frame and the clamp on the pendulum, and tighten the clamps. Where applicable, operate the knife to produce the required slit. Set the pointer if lifted, against its stop. Sharply depress the pendulum release mechanism and holding it down, gently catch the pendulum by hand on its swing without disturbing the position of the pointer, if fitted. Record the reading as is displayed.

1.3.4 *Calculation and expression of results.*

From the scale reading calculate the tearing resistance and tear index as follows,

$F = F' p/N$, (6)

and

$X = F/g$. (7)

Where F is the tearing resistance expressed in mill-Newton.

$F'$ is the mean scale reading, expressed in mill-Newton.

p is the number of sheets torn simultaneously for which the pendulum scale has been calibrated to give as a direct tearing resistance reading, in mill-Newton.

N is the number of sheets torn simultaneously.

X is the tear index, expressed in mill-Newton per square meters per gram.

g is the basis, expressed in grams per square meter.

1.4 Bursting Strength:

1.4.1 Definitions:

- Bursting strength:
  The maximum uniformly distributed pressure, applied at right angles to its surface, that a single sheet of paper can withstand under the test conditions.
- Burst index:
  The bursting strength of the paper divided by the basis weight of the conditioned paper determined by the standard method test.

1.4.2 Principle:

A test piece, placed over a circular elastic diaphragm, is rigidly clamped at the periphery but free to bulge with the diaphragm. Hydraulic fluid is pumped at a constant rate, bulging the diaphragm until the test piece ruptures. The bursting strength of the piece is the maximum value of the applied hydraulic pressure.

1.4.3 Procedure:

Place the sample above the diaphragm keeping it in a position so as the clamp will encompass and subject a total clamped sample. Press the start knob and wait for the sample to rupture. The display shows the bursting strength in kilopascals. For each hand sheet repeat at least two times and record the values.

1.4.4 Expression of Results:

The bursting strength P is calculated form the average values of the readings per test piece. If more than one test sheet is used then the following expression will be used to evaluate,

$$P = B/N \qquad (8)$$

Where B is the mean value of the maximum hydraulic pressure in kilopascals.

N is the number of sheets tested simultaneously.

The burst index, X, expressed in kilopascals square meters per gram, may be calculated from the bursting strength by the formula.

$$X = P/g \qquad (9)$$

Where g is the grammage of the test sheet in grams per square meter.

# Annex 6. Chemical analysis

**Methodology used**

Atomic Absorption Spectrophotometry method was used for the analysis of metal ions. The Instrument used was the Atomic Absorption Spectrophotometer (AAS), Analyst 300 series. Procedures applied are those recommended in the Atomic Absorption manual titled "Analytical Methods for Atomic Absorption Spectrophotometry".

For the analysis of anions including Total Nitrogen (Nt), Nitrogen as $NH_4$-N, Nitrites ($NO_2^-$), Nitrates ($NO_3^-$), total Phosphorous, COD and BOD methods used were obtained from the *"Standard Methods for the Examination of Water and Wastewater"*, 19th Edition 1995, Edited by Andrew D. Eaton, Lenore S. Clesceri and Arnord E. Greenberg. The analysis of anions required use of colorimetric method where a UV-visible instrument (Shimadzu 240) was used.

The Walkley-Back method was used for the analysis of the total organic carbon.

In the analysis of amino acids and sugars, a High Performance Liquid Chromatograph (HPLC- Shimadzu RF-10A XL Instrument) was used.

In the measurement of Redox Potential Potentiostat, PGSTAT20 was used.

In the measurement of pH and conductivity a Philips PW 9420 and Phillips PW9529 pH meter and conductivity meters, respectively were used.

Haache viscometer VT01/VT02 was used in the measurement of viscosity.
Accuracy for the instruments used was within 0.001 mg $L^{-1}$.

| | SAMPLE CODE | | | |
|---|---|---|---|---|
| **PARAMETERS** | **SLJ** | **DCE** | **HME** | **FTE** |
| pH | 4.2 | 4.9 | 5.1 | 4.6 |
| Viscocity (cp) | 3.132 | 0.928 | 0.945 | 0.966 |
| Conductivity(mS/cm) | 8.95 | 18.75 | 5.29 | 19.91 |
| Redox potential (V vs SHE) | 0.52 | 0.81 | 0.57 | 0.71 |
| Density (g/cm3) | 1.0185 | 1.0102 | 1.0039 | 1.0148 |
| BOD5 (mg/L) | 180 | 8.77 | 254.38 | 91.5 |
| COD (g/L) | 62.67 | 7.26 | 13.54 | 18.78 |
| Suspended solids (g/L) | 3.706 | 0.541 | 0.612 | 0.904 |
| Total Nitrogen (mg/L) | 1,113.44 | 117.82 | 273.68 | 154.87 |
| Nitrogen as NH4-N (mg/L) | 145.03 | 14.2 | 67.47 | 67.61 |
| Nitrites (mg/L) | 0.004 | 0.061 | 0.164 | 0.107 |
| Nitrates (mg/L) | 2.84 | 21.95 | 6.5 | 7.52 |
| Total Phosphorus (mg/L) | BDL | 27.45 | 90.92 | 59.82 |
| Total Organic Carbon (g/L) | 17.65 | 1.81 | 3.02 | 7.16 |
| Sodium (mg/L) | 11.54 | 965.13 | 69.41 | 915.28 |
| Potassium (mg/L) | 244.61 | 106.32 | 340.22 | 209.14 |
| Magnesium (mg/L) | 443.23 | 752.01 | 351.73 | 785.01 |
| Calcium (mg/L) | 691.41 | 557.38 | 351.01 | 528.52 |
| Iron (mg/L) | 37.05 | 4.64 | 12.53 | 7.88 |
| Manganese (mg/L) | 0.84 | 20.14 | 0.82 | 18.33 |
| Boron (mg/L) | BDL | BDL | BDL | BDL |
| Copper (mg/L) | 1.15 | 0.11 | 0.14 | 5.51 |
| Zinc (mg/L) | 6.76 | 0.68 | 1.85 | 0.75 |
| Sugars (g/L) | 46.34 | 9.19 | 13.15 | 15.42 |
| Total Organic Acids (g/L) | 26.48 | 6.26 | 1.31 | 2.21 |
| Ammino Acids (g/L) | 16.29 | 3.63 | 7.42 | 2.54 |
| | | | | |
| **Sample content (Composition%)** | | | | |
| Dry matter | 8.79 | 2.61 | 2.24 | 4.56 |
| Sugars | 4.55 | 0.91 | 1.31 | 1.52 |
| Ash content | 1.45 | 1.26 | 0.47 | 1.47 |
| Organic acids | 2.6 | 0.62 | 0.13 | 0.22 |
| Total Nitrogen | 0.11 | 0.01 | 0.03 | 0.02 |
| Total Phosphorus | NIL | <0.01 | 0.01 | <0.01 |

# Annex 7. Summary of costs for equipment construction

| Description | Cost (US$) |
|---|---|
| Design of the Hammer Mill (Intl. Expert) | 60,550 |
| Construction of the Hammer Mill (TATC) | 64,330[1] |
| Civil Structure (New Builders) | 4,635 |
| Modification of Sisal Chippers (TATC) | 10,069 |
| Roller Crusher (TATC) | 3,740 |

[1] Of which US$ 7,761 for the support structure, feeding conveyors, and trolley and US$ 56,569 for the hammer mill itself.

**Annex 8.**

# KATANI LIMITED

## Feasibility Study for Pilot Pulpable Fiber Production Using Fiber Extraction Plant (FEX)

**Final Version**

Prepared by:
Katani Limited
P.O. Box 133
Tanga, Tanzania
FEBRUARY 2006

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**ABBREVIATIONS:**

| | |
|---|---|
| ADMT | Air Dry Metric Tons |
| ARI | Agricultural Research Institute |
| BKS | Bleached Kraft Softwood |
| CEPS | COAID Enhanced Production Systems |
| CFC | Common Fund for Commodities |
| CIF | Cost, Insurance and Freight |
| COAID | Canada Overseas Agro-Industrial Development Organization |
| COMFAR | Computer Model for Feasibility Study and Reporting |
| cm | centimetre |
| CVs | Curriculum Vitae |
| FAO | Food and Agricultural Organization of the United Nations |
| FC | Foreign Currency |
| FEX | Fibre Extraction Plant |
| FOB | Free On Board |
| H.11648 | Hybrid number 11648 |
| HP | Horse Power |
| HM | Hammer Mill |
| HZ | Hertz |
| ICB | International Commodity Body |
| IFAD | International Fund for Agricultural Development |
| IGHF | Intergovernmental Group on Hard Fibres |
| IRR | Internal Rate of Return |
| ISO | International Standards Organization |
| KEPHIS | Kenya Plant Health and Inspectorate Service |
| Kg | Kilogramme |
| Km | Kilometre |
| KSB | Kenya Sisal Board |
| KVA | Kilo Volt Amperes |
| kWh | kiloWatt hours |
| Ltd | Limited |
| MIM | Mkonge Investment and Management Company Ltd |
| MOD | Miscellaneous Obligation Document |
| mm | millimetre |
| MT | Metric Tonne |
| PEA | Project Executing Agency |
| R&D | Research and Development |
| rpm | revolutions per minute |
| TATC | Tanzania Automotive Technology Centre |
| TANESCO | Tanzania Electric Supply Company Limited |
| TSA | Tanzania Sisal Authority |
| TSB | Tanzania Sisal Board |
| TSH | Tanzanian Shilling |
| UNIDO | United Nations Industrial Development Organization |
| US$ or USD | United States Dollar |

## 1.0 EXECUTIVE SUMMARY

### *1.1 Project Background:*

Katani Limited 1 Tasma Road, Bombo P.O. Box 123, Tanga, Tanzania is requesting the Common Fund for Commodities (CFC) for a loan to finance investment in the production of sisal fibre for pulping. Katani Limited is a private company owned by Africa Mpya Limited (90% shares) and Mkonge Investment and Management Company (MIM) owned by 87 former employees of Tanzania Sisal Authority (10% of the shares). The company has a 7-member Board of Directors and an Executive Board comprising of the Managing Director, the Executive Director, the Director of Finance and the Director of Planning. The Executive Board handles the day to day running of the company. Katani Limited owns 5 sisal estates with a total land holding of 20,309 hectares mainly in Korogwe District within a radius of 150 km from Tanga port and a spinning and weaving mill located at Ngomeni (25 km from Tanga) with an installed capacity of 20,000 tons per year of high quality woven products, twines and ropes. Katani Limited has since 1998 been the project implementing company in Tanzania for the project on "Product and Market Development for Sisal and Henequen Products". The company has broadened ownership by involving smallholders and outgrowers and intends to increase commercial utilization of the sisal plant through accelerated research and development of products and markets in which sisal enjoys technological and logistic advantages.

A review and inventory of existing technologies, new technologies and machinery was undertaken in the previous project. Preliminary test runs were carried out after a prototype hammer mill and roller crusher was manufactured by Tanzania Automotive Technology Centre in 2002 and 2003. Fibre was pulped in Moshi Pulp and Paperboard Mill. The pulped fibre was analyzed in Europe and at Mufindi Paper Mill. Pulp and fibre samples were then dispatched to interested mills in Europe, Brazil, Canada and USA for evaluation. Operating parameters and cost profiles were determined and analyzed and confirmatory analysis on fibre versus pulp quality was undertaken. The results led to a selection of the hammer mill as the suitable technology for fibre extraction.

### *1.2 Market Analysis and Marketing Concept:*

New uses of sisal fibre have emerged especially in its utilization for the production of pulp and paper. Sisal pulp can be used to produce specialty paper for bank notes, electrolyte paper, coffee filters, tea bags, oil and fuel filters, cigarette papers etc. The current market for specialty pulp is estimated at 250,000 tons growing at 5-6% per annum in the last four years. Current production of sisal in this usage is around 45,000 tons per annum growing at the same rate. The fibre required to produce this pulp is around 90,000 tons per annum. The price of unbleached and bleached sisal pulps ranges from US$ 1,200 to US$ 2,300 per air-dry metric ton (ADMT) CIF Europe.

Reinforcement pulp is another potential market for sisal pulp. Bleached Kraft Softwood (BKS) is the main reinforcement pulp. Total market demand for reinforcement pulp is around 15 million ADMT growing at 9% per annum in the last 9 years. The current price of BKS is around US$ 650 per ADMT CIF Europe. Despite willingness by pulp mills to pay a premium of up to 12% for sisal fibre over softwood pulp, the price is presently not sufficient to cover production costs. Thus this usage is not targeted in the present proposal.

The main project (business) strategy is to reduce production costs of staple fibre to enable sisal specialty pulp price compete with wood and other crop fibres and thereby increase its demand in pulp production. The project will concentrate on niche markets for specialty applications where properties of sisal such as porosity are as good as other fibres. It is possible to capture a significant portion of the staple sisal fibre market for sisal pulp production by cultivating sisal under enhanced production systems and using new fibre extraction technology.

Main competitors of sisal in specialty pulp are abaca pulps due to their strength and viscosity; flax pulp for currency/security and cigarette papers; and hemp and jute pulps for cigarette papers. Prices of abaca are 60% higher than sisal. Generally, prices of flax, hemp and jute pulps are similar to that of sisal. Prices of sisal pulp are about twice as much as BKS. In the short-term sisal pulp cannot effectively compete with softwood pulp in the reinforcement pulp market unless fibre prices (which account for 40% of the pulp cost) are drastically reduced.

### *1.3 Material Inputs:*

All main raw materials required for the fibre extraction process are available locally. These are fresh sisal leaves and water. The maximum plant capacity will be 20 tons per hour or about 140 tons of sisal leaves per 7-hour shift. In the 3-hammer mill scenario smallholder and outgrower farmers will plant a total of 1,890 hectares over the project period. The 2-hammer mill scenario requires 945 hectares planted. In both scenarios smallholders and outgrowers will supply raw materials in terms of sisal leaves and boles to the project. In the 3-hammer mill scenario around 27 cubic metres of water will be used per hour or 189 cubic metres per 7-hour shift.

### *1.4 Location, Site and Environment:*

Due to the existing Katani establishment and corporate structure, location of the FEX plant was limited to one of the 5 estates Katani owns. Proximity to raw materials (sisal leaf supply) and Tanga port were the conditions considered. Hale estate is the nearest to the Tanga Port compared to the other 4 Katani estates. The site for commercial scale FEX plant will be where the first hammer mill was installed. It is located 70 km from Tanga Port. The site has the required land and is also the site for the biogas plant which will use the waste from the FEX project, solve the problem of sisal waste disposal and provide the energy required for running the machines and for drying the fibre. The river Pangani runs a few metres from the site and a concrete diversion channel draws water from the river for use at the stationary decorticator presently installed close to the first hammer mill.

### 1.5 Project Engineering:

To produce sisal fibre for pulp production, it was found necessary to change the fibre extraction technique from traditional decortication to the hammer mill technology. The new fibre extraction technology still requires cutting of leaves and leaf transport. At the mill site leaves will be fed into a chipper, chipped into 7cm length and thereafter hammer milled producing wet fibre, which will be dried before baling and selling. The new technology was intended to produce fibre from the leaf and the bole to increase yield of fibre per unit area. The technology was also expected to recover more efficiently the short fibres from the leaf butt ends, not done in conventional decorticators. During trials, the bole fibre was efficiently extracted by the hammer mill but could not be pulped together with leaf fibres, as it required different pulping conditions.

The trial results also showed that to produce clean fibre two passes were required. Two scenarios were evaluated. One consisted of two hammer mills and the other consisted of three hammer mills. The hammer mills have the same capacity. The 2-hammer mill scenario is based on one hammer mill doing the first pass and the second hammer mill doing the second pass while the 3-hammer mill scenario consists of two hammer mills performing the 1st pass and a third hammer mill doing the second pass. The 2-hammer mill scenario was considered to be under utilizing the second pass hammer mill, as the material from the first pass is only 50% of the weight of material fed at the beginning. It is therefore recommended that two first pass hammer mills feed the third hammer mill.

In the recommended hammer mill scenario the first pass will involve 20 tons of fresh sisal chips (10 tons per mill) processed to produce wet sisal fibre with additional water supplied at the rate of 16.8 cubic metres per hour (8.4 cubic metres per hour per mill). The capacity of the plant will be 5.6 tons of dry sisal fibre per 7-hour shift. Fibre yield is projected at 4.0% of fresh leaves by weight. The parenchyma content of the sisal fibre will be around 15% of the throughput weight. The 2nd pass in the third hammer mill will have water injected at a rate of 10.2 cubic metres per hour. The final output will be wet sisal fibre per hour with moisture content of 71%, which must be dried to a moisture content of around 10% mechanically. The yield of the sisal fibre after drying will be around 800 kg per hour with parenchyma content of about 5%. The fibre from the third hammer mill will be conveyed to a squeezer and carding machine before drying in a mechanical dryer using biogas without a boiler and baled in a hydraulic press. The hammer mill fibre extraction efficiency was found to be around 99% compared to fibre extraction efficiency in conventional decorticators of around 80%.

Three Oxidation ponds are provided in the project to treat the wastewater from the extraction process. About 315 tons of wastewater will be produced per day. After treatment, the solid dried product will be used as fertilizer on the estate and water used for irrigation.

Technical staff required will be recruited mostly from local personnel involved in the pilot phase of the project. Katani Limited has set aside at Hale estate about 65 km from Tanga, 1,890 hectares for sisal growing under CEPS mode using smallholders and outgrowers.

## 1.6 Organization and Management:

The project will operate under a new subsidiary company of Katani Limited which shall be established under the company law - cap. 212. It will have a Board of Directors selected by Katani Limited and collaborating partners. The Board of Directors will be responsible for all policy issues, general guidance and overall supervision of the company. A Project Manager will be appointed to do the day to day running of the project in order to ensure the strategic objectives and policies are implemented. His duties will include planning, coordination, personnel and finance management and preparation and submission of periodic reports to the Board. He will be assisted by an agricultural officer in field activities, an accountant in administration and accounting functions and technicians and supervisors at the fibre extraction facility. The marketing function will be undertaken at the Headquarters of Katani Limited.

## 1.7 Human Resource:

The growing of sisal, maintenance, harvesting and leaf transport to the FEX plant will be undertaken by smallholders/outgrowers and their families. The project will provide tractors, trailers and equipment to facilitate the farmers but they will pay for the services. A maximum of 10 tractor drivers are envisaged to service the smallholder and outgrower farmers. The project will grow and maintain ENT nurseries and sale seedlings to farmers for planting their fields.

At the maximum, the 3-hammer mill scenario 90 mill workers and 11 estate workers will be required compared to 47 mill workers and 6 estate workers in the 2-hammer mill scenario. Most workers will come from surrounding villages and present estate workers families except for managerial and professional staff. Mill workers will be recruited from youths and women for unskilled tasks to help these economically disadvantaged groups in the Tanzanian society. The majority of mill workers will be unskilled when first employed. In the 3-hammer mill scenario a maximum 9 management and skilled staff will be engaged by the Project compared to 8 in the 2-hammer mill scenario. Administrative support staff in both cases will be 5 semi-skilled workers. The total number of employees in the 3-hammer mill scenario will be 114 at the maximum compared to 66 in the 2-hammer mill scenario.

## 1.8 Implementation Schedule:

The project duration of 11 years includes two and a half years of construction and optimization of the FEX plant. In the 2-hammer mill scenario a total of 420 hectares of field sisal will be planted during the construction period and continue thereafter to reach 945 hectares by the end of the project. A total of 17 hectares of nursery will be established in the first year, 6 hectares in the second year and 5 hectares each year thereafter. In the recommended 3-hammer mill scenario a total of 840 hectares of field sisal will be planted during the construction period and continue thereafter to reach 1,890 hectares by the end of the project. A total of 34 hectares of nursery will be established in the first year, 12 hectares in the second year and 10 hectares each year thereafter. Production in both scenarios commences after the construction period and lasts for 8 years. Main activities during the production period will be sisal leaf harvesting, staple fibre production and sale in local and export markets.

### *1.9 Investment and Financial Results[1]:*

The main objectives of the two scenarios are:

(i) In the 3-hammer mill scenario, to cultivate 1,890 hectares of sisal under intensive CEPS system starting with 510 hectares in year 1, 180 hectares in year 2 and 150 hectares annually from year 3 onwards while in the 2-hammer mill scenario 945 hectares would be cultivated starting with 255 hectares in year 1, 90 hectares in year 2 and 75 hectares thereafter. Harvesting in both scenarios commences 24 months after planting and continues for 8 years.

(ii) To produce 5.6 tons per 7-hour shift or 4,576 tons of staple sisal fibre per annum by year 2015 in the 3-hammer mill scenario while production under the 2-hammer mill scenario would be 2.8 tons per shift or 2,285 tons per annum.

(iii) To generate revenue from sale of staple fibre at the price of US$ 600 per ADMT F.O.B. Tanga for exports and US$ 625 per ADMT for local sales. This applies to both scenarios.

Total capital costs for the 3-hammer mill scenario are US$ 3,222,110 while total capital costs for the 2-hammer mill scenario are US$ 2,079,340. Working capital requirements in the 3-hammer mill scenario are estimated at US$ 360,480 and in the 2-hammer mill scenario US$ 183,260.

Project financing in both scenarios is to come from Katani Limited and the Common Fund for Commodities.

In the 3-hammer mill scenario Katani Limited will provide equity of US$ 613,737 in cash and kind. CFC has provided a grant of US$ 401,195 for the pilot hammer mill system and the second hammer mill for optimization of the process. CFC will further provide a soft loan of US$ 976,750 (excluding capitalized interest) disbursed in the second and third years of the construction phase. The total disbursed loan including capitalized interest will be US$ 1,111,530.

In the 2-hammer mill scenario Katani equity would be US$ 301,525 in cash and kind and the same CFC grant of US$ 401,195 for the pilot hammer mill system and second hammer mill for optimization would apply. A soft loan of US$ 595,930 (excluding capitalized interest) disbursed in the second and third years of the construction phase would be required from CFC. The total disturbed loan including capitalized interest will be US$ 675,929.

The loan is repayable in 5 equal annual installments with an interest rate of 4% and a fee of 2% per annum charged on the outstanding balance. A grace period of 2 years after the construction period is sought.

In the 3-hammer mill scenario the total capital invested is recovered by 2014 after discounting the net cash flows while the total equity invested is recovered by 2012. The IRR to total capital invested is 19.13% with a net present value at 12% discount rate on US$ 780,140 while IRR to total equity invested is 34.82% with a net present value at 20% discount rate is US$ 533,435. In the 2-hammer mill scenario the total capital invested is recovered by 2016 and the total equity invested by 2013. The IRR to total capital invested is

[1] All figures and results reported in this document have been calculated with UNIDO's software for project preparation and appraisal, COMFAR III Expert. The detailed financial statements and graphical charts are attached in Annex 4 (2-Hammer Mill alternative) and Annex 5 (3-Hammer Mill alternative).

13.59% with a net present value at 12% discount rate of US$ 101,896 while IRR to total equity invested is 35.10% with a net present value at 20% discount rate of US$ 223,461. Both are higher than the 12% discount rate used in the financial analysis. These results indicate both scenarios are financially viable but the 3-hammer mill scenario is more viable and attractive.

The feasibility of the technology will be confirmed after operating a pilot plant with two hammer mills for at least 2 months in 2006. There is presently only one hammer mill being used for both the first pass and second pass. A feeding system for the first hammer mill and collector and discharge conveyors for the second hammer mill is under manufacture at TATC to enable the system operate continuously. There is a market for sisal fibre in the specialty pulp market, which the project will exploit. Once the risks are minimized, the project's financial viability will be enhanced and made more attractive to Katani Limited and will be a major step towards reviving the sisal industry in Tanzania. Adverse environmental effects are not envisaged. It is strongly recommended to make funds available for implement the project with 3-hammer mills.

## 2.0 PROJECT BACKGROUND AND BASIC DATA

### *2.1 Project Sponsors*

Katani Limited of 1 Tasma Road, Bombo P.O. Box 123, Tanga, Tanzania is sponsoring the project. Katani Limited is a private company owned by Tanzanians. Africa Mpya Limited holds 90% of the shares while Mkonge Investment and Management Company (MIM) owned by 87 former employees of Tanzania Sisal Authority holds 10% of the shares. The company has a 7-member Board of Directors and an Executive Board comprising of the Managing Director, the Executive Director, the Director of Finance and the Director of Planning. The Executive Board handles the day to day running of the company. Katani Limited has been central to the development of the sisal industry in Tanzania since privatization of Tanzania Sisal Authority (TSA) in 1997. It currently owns five sisal estates, namely: Hale estate (4,180 ha), Mwelya estate (2,399 ha), Ngombezi estate (4,000 ha), Magunga estate (6,520 ha), and Magoma estate (2,630 ha) totaling 20,309 hectares. The estates are mainly in Korogwe District but two also have land in Handeni District. All are located along the main tarmac roads and railway line from Dar es Salaam and Tanga to Arusha. They are within a radius of 150 km from Tanga port, the second largest port in Tanzania, after Dar es Salaam. Katani Limited also owns a spinning and weaving mill located at Ngomeni (25 km from Tanga) on the main tarmac road from Tanga to Dar es Salaam and Arusha. The mill has an installed capacity of 20,000 tons per year and uses sisal fibre from the estates for production of high quality woven products, twines and ropes. Katani Limited has since 1998 been the project implementing company in Tanzania for the project on "Product and Market Development for Sisal and Henequen Products".

Katani Limited has a vision to create by 2013 a vibrant integrated sisal company, widely owned, and contributing significantly to the economy of Tanzania by producing valued-added sisal products for local and export markets. Its mission is to transform the company, within the next 10 years, into a leading sisal processing and marketing concern.

To achieve this, the company envisages to:

- Broaden ownership by encouraging smallholders and outgrowers to acquire land and grow sisal as well as food crops and by franchising primary and secondary processing;
- Raise utilization of the sisal plant from the current 2% to more than 80% in ten years with emphasis on better utilization of land, human resources and capital assets;
- Accelerate the commercialization of research results to produce and market new products where sisal enjoys technological, logistical and market advantages.

### *2.2 The Role of the Sisal Industry in the Tanzanian Economy*

Sisal is grown in Tanzania, Kenya, Madagascar, South Africa, Brazil, China, Cuba, Venezuela, Jamaica, Haiti and other tropical countries. It is indigenous to Central America. Sisal used to be the largest foreign exchange earner for Tanzania contributing up to 30% of the value of exports and the largest employer up to the early 1980's. Production peaked at 230,000 in 1964 but has since declined to 26,758 tons in 2004.

In the 1950's and 1960's, sisal was the most important export commodity in Tanzania contributing up to 30% of the value of exports followed by coffee (15%), diamonds (10%) and others (30%) and provided more than 25% of the employment opportunities in the country. It is the only crop in which Tanzania excelled internationally. Loss of market share to synthetics, change of technology of baling hay and straw, low utilization of the sisal plant and ever rising production costs were the main causes of the decline. Nationalization of most estates in the mid-1970's and inappropriate economic policies accelerated the decline. Despite the decline, sisal estates still have the necessary infrastructure in place, experienced manpower and it still supports many families in Tanga Region where most sisal estates are found. Due to this, the Government supports and accords high priority to sisal rehabilitation and development programs.

## *2.3 Project Background*

The basic idea of the project dates back to 1980's when the then Tanzania Sisal Authority (TSA) in collaboration with development partners began serious attempts to develop new end uses for sisal. This follows decades of decline of the sisal industry due to low fibre prices in the world market, change in technology of baling hay and straw and erosion of market share by synthetic substitutes. At its 5$^{th}$ and 6$^{th}$ meeting, the CFC Consultative Committee examined a project proposal submitted by the Intergovernmental Group on Hard Fibres (the International Commodity Body-ICB). The Committee recommended simplification of the project by deleting some elements. The proposal was revised and resubmitted to the 10$^{th}$ meeting of the Committee. The Committee agreed with the broad objectives of the project but recommended that geotextiles be removed, emphasis be placed on pulp and paper, animal feed, manure and peat moss, and the Secretariat assist the ICB in formulating the project. UNIDO, IFAD, CFC and FAO collaborated with Tanzania and Kenya in redesigning the project and submitted a report in December 1994. The report was considered by the FAO-IGHF meeting in Colombo in April 1995. The IGHF approved the project and recommended it for financing by CFC. The 14$^{th}$ and 15$^{th}$ Consultative Committee meetings considered the revisions of the proposal and requested refinement of the project design and inclusion of financial evaluation of the pilot operations to be financed by the loan. It directed the Secretariat to take up the technical details and co-financing possibilities with UNIDO (as the PEA) and FAO (as ICB), review project costs and streamline loan conditions due to the pilot nature of the project and due to Tanzania being a least developed country. The revised proposal was resubmitted to the CFC Executive Board and approved in November 1996.

In 1997 implementation of the project "Product and Market Development of Sisal and Henequen Products" was started targeting specific research and development programs. These were aimed at responding to the producers' needs to improve efficiency of cultivation, harvesting, and processing with a view to increasing productivity and greatly reducing costs. One of the core activities of the project was to carry out research and development in production of sisal fibre for pulping at a cost competitive to other fibres from wood, abaca, cotton, flax, hemp and kenaf. A two-stage research program was envisaged covering screening of available technology for production of pulpable fibre and use of the selected technology on a pilot basis to produce enough fibre for pulping. The research trajectory was not so much based on additional experiments in fibre and pulping but in confirmatory analyses. It was considered more pressing to confirm process and cost data on fibre and pulp production in the pilot production runs. The information from pilot production runs and market trials was to provide a sound basis for a technical and economic feasibility study for a fibre extraction project and a pulp mill.

The first thing done was to undertake a review and inventory of existing technologies and propose technologies and machinery to be tried. Preliminary test runs were carried out after a prototype hammer mill and roller crusher was manufactured by Tanzania Automotive Technology Centre in 2002 and 2003. The results led to a selection of the hammer mill as the suitable technology for fibre extraction.

Equipment and machinery was originally to be purchased or leased for pilot fibre production, pulping and for confirmatory tests but when no source could be found in the world for the hammer mill and roller crusher the equipment had to be fabricated locally. The fibre was pulped in Moshi Pulp and Paperboard Mill. The pulped fibre was analyzed in Europe and at Mufindi Paper Mill. Pulp and fibre samples were then dispatched to interested mills in Europe, Brazil, Canada and USA for evaluation. Operating parameters and cost profiles were determined and analyzed and confirmatory analysis on fibre versus pulp quality was undertaken. The pilot processing results together with the productivity improvement efforts made in sisal production were expected to considerably bring down the cost of production for the fibre making it more effectively competitive in pulp and papermaking.

The pilot production of pulpable fibre was envisaged to cost US$ 1.25 million financed from a loan at concessionary terms. It was to be established before the pilot pulp runs started.

The current project has conducted studies for developing new varieties and better agricultural practices under sub-components A.3 on variety trials in estates and A.4 on smallholder production in Kenya and Tanzania. These studies aim at increasing the sisal fibre production per hectare per year and reducing the production costs. Su-component C.1 on selection of technology for a fibre extraction facility is addressing the issues linked to fibre extraction from sisal leaves and boles. Under this sub-component, Katani Ltd was awarded a contract to evaluate hammer milling and roller crushing technologies as two potential technologies for efficiently extracting pulpable export grade fibre from the sisal leaves and boles of the sisal plant. Katani Ltd was also to determine the technology, basic unit size and technical and cost parameters for designing a 6.8 ADMT pulpable fibre per day FEX demonstration plant. The project was to be implemented in Tanzania and financed by the loan approved by the Common Fund for Commodities.

The expected output of the local contract was to produce a feasibility study for the FEX demonstration plant, which included evaluation of different scenarios based on number of shifts and technical alternatives in the layout. The different scenarios and related sensitivity analyses were to serve as a decision making tool. Unfortunately the optimization of the hammer mill system through provision of a bigger chipper, a chipper feeding system, a second hammer mill, a larger drying area, collector and discharge conveyors has been delayed due to delays in clearance of imported parts from the port. The capacities used in the present study need to be reconfirmed when the machinery and facilities are in place. This will only be possible after June 2006. In the meantime Katani Limited has already mobilized funds for its equity injection into the project.

## 2.4 Market Study and Trials

In 1998, Sevenhuijsen Associates of the Netherlands was contracted to undertake phase 1 of the market study for sisal pulp. The main objective of the study was to establish the potential demand for sisal pulp in different paper applications and identify future contacts in mills, which are potential buyers of sisal fibre and sisal pulp. The terms of reference for the study included:

(i) Estimating realistically the possible demand potential for sisal pulp and its use in different sectors (specialty, semi-specialty and reinforcement);
(ii) Establishing realistic market premium prices for sisal pulp;
(iii) Establishing market contacts for future operations.

Expected outputs of the study included a comprehensive market study showing the potential market demand for sisal pulp and its use in different sectors of paper production and a list of pulp and paper mills with interest in further participation in market study phases 2 and 3.

From the study 16 mills interested in receiving sisal fibre samples and 29 mills interested in sisal pulp samples were short-listed for further visits and contacts. A total of 19 firms in reinforcement and specialty pulp business were contacted physically. Mr. Salum Shamte a marketing consultant from Katani Limited visited and discussed with companies based in Europe, Dr. Walid Khayrallah in Canada and Dr. Rosely M. V. Assumpcao in Brazil. These firms were found to be potential partners and customers for both sisal fibre and sisal pulp.

Mr. Salum Shamte visited 11 companies involved in reinforcement and specialty pulping and paper making in Europe and 2 mills in Tanzania in June and July 2004.

The main conclusions of Mr. Shamte's report on his market visits and discussions were:

- Bleached sisal pulp properties make it suitable for use in the specialty pulp market. Sisal properties for porosity, tensile and tear are lower than abaca but abaca prices are around 60% higher than those of sisal. Properties and prices for sisal, flax, hemp and jute pulps are similar or only differ slightly depending on customers' specifications and requirements. The current market was estimated at about 250,000 tons growing at a rate of 5-6% per annum in the last four years. Current sisal pulp production was reported as being 45,000 tons growing at the same rate as above. The prices for bleached and unbleached sisal pulp range between US$ 1,500 - US$ 1,700 per ton, and US$ 1,400-US$ 1,600, CIF Europe, respectively.
- The aspect ratio, tear and tensile index, which are key properties for reinforcement pulps, are better for sisal than softwood pulps. The current market for Bleached Kraft Softwood as reinforcement pulp was estimated at about 15 million, growing at 9 percent per year. The current price for BKS is around US$ 650 per ton at paper mill gate. To compete, the price of sisal pulp has to be around US$ 750 per ton. Mills indicated willingness to pay a premium price of 12% over BKS. Thus reinforcement pulp was not considered as the target product for this proposal.

## 2.5 *Screening and Evaluation of Selected Sisal Varieties*

In an endeavor to develop new market opportunities for sisal, the Project financed a study on the development and confirmation of technologies geared towards sisal pulp production, through improved varieties and field and crop management practices. This included establishment of two Meristematic Tissue Culture laboratories at ARI Mlingano in Tanzania and at KEPHIS Muguga in Kenya for micro-propagation. The main objective of micro-propagation was rapid multiplication of large numbers of plants to generate high quality homogeneous planting materials identical to the elite mother plants, which were the source.

The major aim for doing all these activities was to increase productivity and greatly reduce costs. The project conducted variety and fertilizer trials at ARI Mlingano, Hale and Gomba Sisal Estates between 1997 and 2004. This culminated in the establishment of CEPS trials at Hale Estate, 3-factor variety trials at ARI Mlingano and fertilizer trials at Gomba Estate. Two main components of CEPS at Hale estate that needed confirmation were high density planting together with an enhanced field and crop management systems, and whole-plant harvesting from year 3-4 after field establishment.

CEPS trials were designed with the emphasis on using the total biomass from the whole plant for the purpose of producing pulpable fibre. The Gomba fertilizer trial was designed and implemented with emphasis on finding the most suitable combination of fertilizers for increased productivity per hectare. Several fertilizer combinations using sisal waste were also evaluated.

The main findings of the study were:

i) Under proper nursery management, sisal bulbil nurseries produced vigorous and healthy plants ready for transplanting after 6 months as opposed to the traditional 18 - 24 months.
ii) Hybrid 11648 generally performed better than the other 3 varieties (Mlola 487, Hildana and Sisalana) in terms of yield and other responses.
iii) The first cut was done at 24 months after planting, a very significant reduction from the traditional 36 months to 48 months.
iv) For production of sisal fibre for pulping, the optimal density was found to be 6,666 plants per hectare instead of the 3,200 plants and 4,000 plants per hectare traditionally used.
v) The bole produced lower quality pulp and required more time and chemicals to pulp casting doubt on its suitability for commercial pulpable sisal fibre production, and apparent advantage to produce pulp from the whole plant.

The above results form the core of the assumptions used in this feasibility study.

## 2.6 *Selection of fibre extraction technology*

Katani Limited and the project established that conventional fibre extraction is not very efficient, as there are fibre losses of about 15 to 20% as flume tow. In addition, sisal fibre produced using conventional decorticators had a high cost of production thus making sisal not competitive.

The project on "Product and Market Development for Sisal and Henequen Products" evaluated the two processes of hammer milling and roller crushing. Experience gained by three engineers from Tanzania and Kenya in the Netherlands in 1999 and in Brazil in 2000 recommended the two technologies of roller crushing and/or hammer milling as two possible extraction methods which could process fibre from sisal leaf, bole and whole plant. Preliminary work done on the roller crusher and hammer mill pointed to the hammer mill as the technology most suitable for fibre extraction. The mill was operated from May 2004 to September 2004 but due to limitations in feeding, parenchyma removal and drying, the mill did not operate for more than 15 minutes continuously at any one time. The feed conveyor for the mill had a capacity of 10 tons of chips per hour whereas the capacity of the two chippers was only five tons per hour. As the chippers were manually operated even this 5-ton capacity was not achieved. The feed trailer used to take chips from the chippers had a capacity of two tons of chips. To achieve acceptable levels of parenchyma removal the fibre from the first pass had to be taken back for a second pass in the same mill manually thus reducing the mill capacity to below 20%. Trials to reduce parenchyma from the fibre produced after the second pass by injecting water into the mill screen were successful but the modification was not incorporated in the mill. To produce fibre for pulping and market trials a sun-drying facility was provided but it had a capacity of only 250 kg as opposed to mill output of 3.8 tons per shift if operated optimally. More trials were therefore needed to confirm conclusively the various parameters of the technology such as resilience of the equipment, parenchyma removal, spare parts needed, power and water consumption.

The main conclusions and recommendations from the study were:

- The roller crusher manufactured in Tanzania did not remove parenchyma more efficiently and sometimes damaged the fibre resulting in low pulp yield.
- Combining the roller crusher with the hammer mill gave no advantage to the process.
- Use of water bath washing system required large quantities of water and did not effectively remove parenchyma from the fibre.
- It was recommended to operate two hammer mills in parallel to do the first pass with water injected in the hammer mill screen, and one hammer mill in series to do the second pass with water injected at the dosing feeder and in the second hammer mill screen.
- The system used about $27m^3$ of water per hour. The parenchyma level after the second pass with water injected in the mill screen was around 4.5%. The wastewater produced can be recycled or pumped for field irrigation. It was recommended to optimize water used in reducing the parenchyma content in the fibre produced by the hammer mill.

## 3.0 MARKET ANALYSIS AND MARKETING CONCEPT

### 3.1 *Demand and Market*

Worldwide production of pulp and recovered paper including dissolving pulp in 1998 was around 298 million tons and increased to 328 million tons by 2002 while consumption was 301 million tons in 1998 and increased to 331 million tons in 2002. The figures in table 1 attached show a production and consumption increase of around 10% during the period. South America registered the highest percentage increase in production and consumption of 23% and 33% respectively. In quantitative terms however, Asia and Europe registered the highest production and consumption increase. North and Central America exhibited a declining trend in production and consumption.

The following data in table 1 and 2 was obtained from the latest FAO Yearbook for 1998 – 2002.

**Table 1: Total Pulp and Recovered Paper including Dissolving Pulp**

| | | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|
| **WORLD** | - Production ('000 MT) | 298,025 | 310,986 | 328,997 | 324,722 | 328,132 |
| | - Consumption ('000 MT) | 301,162 | 313,786 | 332,137 | 329,311 | 331,499 |
| | - Imports ('000 MT) | 56,494 | 60,596 | 65,694 | 69,188 | 69,584 |
| | - Imports (Million US$) | 18,519 | 19,670 | 26,803 | 21,438 | 20,688 |
| | - Exports ('000 MT) | 53,366 | 57,798 | 62,553 | 63,598 | 66,216 |
| | - Exports (Million US$) | 16,748 | 17,984 | 24,357 | 18,646 | 18,598 |
| **AFRICA** | - Production ('000 MT) | 3,817 | 3,734 | 4,078 | 4,279 | 4,279 |
| | - Consumption ('000 MT) | 3,401 | 2,948 | 3,364 | 3,768 | 3,668 |
| | - Imports ('000 MT) | 430 | 328 | 394 | 321 | 321 |
| | - Imports (Million US$) | 139 | 122 | 165 | 141 | 216 |
| | - Exports ('000 MT) | 846 | 1,116 | 1,107 | 833 | 931 |
| | - Exports (Million US$) | 445 | 478 | 498 | 398 | 388 |
| **N. & C. AMERICA** | -Production ('000 MT) | 128,128 | 131,438 | 131,518 | 123,440 | 124,347 |
| | - Consumption ('000 MT) | 114,385 | 113,531 | 114,801 | 107,758 | 107,338 |
| | - Imports ('000 MT) | 10,463 | 10,946 | 11,987 | 11,603 | 11,733 |
| | - Imports (Million US$) | 3,197 | 3,441 | 4,487 | 3,510 | 3,274 |
| | - Exports ('000 MT) | 24,207 | 25,854 | 28,703 | 27,285 | 28,742 |
| | - Exports (Million US$) | 8,008 | 8,733 | 11,408 | 8,454 | 8,264 |
| **SOUTH AMERICA** | -Production ('000 MT) | 13,052 | 14,687 | 16,750 | 16,172 | 16,164 |
| | - Consumption ('000 MT) | 9,254 | 10,456 | 12,787 | 11,419 | 12,161 |
| | - Imports ('000 MT) | 997 | 1,026 | 1,187 | 1,060 | 1,122 |
| | - Imports (Million US$) | 439 | 450 | 587 | 474 | 468 |
| | - Exports ('000 MT) | 4,796 | 5,256 | 5,149 | 5,812 | 5,123 |
| | - Exports (Million US$) | 1,838 | 2,107 | 2,875 | 2,219 | 2,075 |
| **ASIA** | - Production ('000 MT) | 70,625 | 74,444 | 443,489 | 82,750 | 83,563 |
| | - Consumption ('000 MT) | 87,294 | 94,958 | 100,637 | 107,136 | 106,932 |
| | - Imports ('000 MT) | 20,341 | 23,032 | 24,437 | 29,131 | 28,690 |
| | - Imports (Million US$) | 5,997 | 6,783 | 9,357 | 7,855 | 7,579 |
| | - Exports ('000 MT) | 3,673 | 2,519 | 3,290 | 4,745 | 5,321 |
| | - Exports (Million US$) | 1,071 | 846 | 1,320 | 1,027 | 1,160 |
| **EUROPE** | - Production ('000 MT) | 77,214 | 84,336 | 91,416 | 91,110 | 93,563 |
| | - Consumption ('000 MT) | 82,263 | 87,191 | 95,467 | 93,988 | 95,969 |
| | - Imports ('000 MT) | 24,018 | 24,902 | 27,318 | 26,655 | 27,329 |
| | - Imports (Million US$) | 8,654 | 8,741 | 12,010 | 9,319 | 9,079 |
| | - Exports ('000 MT) | 18,968 | 22,045 | 23,267 | 23,777 | 24,921 |
| | - Exports (Million US$) | 5,161 | 5,592 | 7,921 | 6,274 | 6,446 |
| **OCEANIA** | - Production ('000 MT) | 5,196 | 5,346 | 5,745 | 5,970 | 6,217 |
| | - Consumption ('000 MT) | 4,565 | 4,700 | 5,082 | 5,241 | 5,431 |
| | - Imports ('000 MT) | 246 | 360 | 375 | 418 | 393 |
| | - Imports (Million US$) | 94 | 132 | 197 | 138 | 143 |
| | - Exports ('000 MT) | 877 | 1,006 | 1,038 | 1,146 | 1,179 |
| | - Exports (Million US$) | 223 | 227 | 335 | 273 | 264 |

**Table 2: Total Paper and Paperboard**

| | | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|
| **WORLD** | - Production ('000 MT) | 779,869 | 814,482 | 833,760 | 827,528 | 838,308 |
| | - Consumption ('000 MT) | 775,605 | 826,785 | 836,379 | 834,381 | 840,187 |
| | - Imports ('000 MT) | 213,540 | 236,659 | 238,866 | 232,459 | 230,800 |
| | - Imports (Million US$) | 160,432 | 163,829 | 171,303 | 163,548 | 159,165 |
| | - Exports ('000 MT) | 217,795 | 224,356 | 236,249 | 225,604 | 229,921 |
| | - Exports (Million US$) | 162,774 | 158,626 | 168,453 | 154,360 | 154,125 |
| **AFRICA** | - Production ('000 MT) | 7,913 | 7,665 | 7,986 | 8,709 | 8,705 |
| | - Consumption ('000 MT) | 11,236 | 12,195 | 10,480 | 11,402 | 11,123 |
| | - Imports ('000 MT) | 4,863 | 6,181 | 4,214 | 4,989 | 4,246 |
| | - Imports (Million US$) | 3,741 | 4,379 | 3,217 | 3,564 | 2,997 |
| | - Exports ('000 MT) | 1,540 | 1,654 | 1,718 | 2,294 | 1,827 |
| | - Exports (Million US$) | 695 | 622 | 655 | 1,080 | 929 |
| **N. & C. AMERICA** | – Production ('000 MT) | 284,199 | 294,059 | 288,983 | 274,978 | 277,311 |
| | - Consumption ('000 MT) | 270,167 | 286,619 | 284,397 | 271,365 | 273,874 |
| | - Imports ('000 MT) | 43,024 | 48,909 | 55,520 | 51,041 | 50,291 |
| | - Imports (Million US$) | 30,754 | 34,066 | 38,243 | 35,420 | 34,525 |
| | - Exports ('000 MT) | 57,058 | 56,348 | 60,107 | 54,653 | 53,805 |
| | - Exports (Million US$) | 37,607 | 36,066 | 40,180 | 37,261 | 33,986 |
| **SOUTH AMERICA** | – Production ('000 MT) | 25,402 | 25,454 | 26,762 | 30,223 | 30,573 |
| | - Consumption ('000 MT) | 30,359 | 29,485 | 30,576 | 32,938 | 32,441 |
| | - Imports ('000 MT) | 8,247 | 6,939 | 7,062 | 6,425 | 5,080 |
| | - Imports (Million US$) | 6,903 | 5,395 | 5,338 | 5,040 | 3,748 |
| | - Exports ('000 MT) | 3,291 | 2,908 | 3,249 | 3,711 | 3,212 |
| | - Exports (Million US$) | 2,273 | 1,800 | 3,854 | 2,179 | 1,972 |
| **ASIA** | - Production ('000 MT) | 225,949 | 241,086 | 248,284 | 254,281 | 255,752 |
| | - Consumption ('000 MT) | 245,326 | 264,111 | 271,087 | 277,216 | 280,347 |
| | - Imports ('000 MT) | 46,682 | 53,148 | 51,802 | 50,912 | 53,101 |
| | - Imports (Million US$) | 29,799 | 33,291 | 35,043 | 33,122 | 33,083 |
| | - Exports ('000 MT) | 27,404 | 30,123 | 29,001 | 27,977 | 28,504 |
| | - Exports (Million US$) | 17,589 | 19,619 | 20,471 | 18,464 | 17,594 |
| **EUROPE** | - Production ('000 MT) | 227,524 | 234,349 | 251,993 | 250,156 | 257,652 |
| | - Consumption ('000 MT) | 208,165 | 223,878 | 228,469 | 231,588 | 231,959 |
| | - Imports ('000 MT) | 106,904 | 117,635 | 98,176 | 115,517 | 113,953 |
| | - Imports (Million US$) | 86,271 | 83,524 | 85,679 | 83,784 | 82,119 |
| | - Exports ('000 MT) | 126,262 | 131,105 | 139,701 | 134,085 | 139,646 |
| | - Exports (Million US$) | 103,574 | 99,443 | 104,003 | 94,148 | 98,340 |
| **OCEANIA** | - Production ('000 MT) | 8,882 | 8,870 | 9,751 | 9,180 | 9,236 |
| | - Consumption ('000 MT) | 10,351 | 10,498 | 11,372 | 9,873 | 10,441 |
| | - Imports ('000 MT) | 3,718 | 3,847 | 4,094 | 3,575 | 4,131 |
| | - Imports (Million US$) | 2,964 | 3,174 | 3,281 | 2,618 | 2,792 |
| | - Exports ('000 MT) | 2,249 | 2,220 | 2,473 | 2,881 | 2,926 |
| | - Exports (Million US$) | 1,036 | 1,076 | 1,199 | 1,227 | 1,303 |

Worldwide production of paper in 1998 was around 780 million tons and increased to 838 million tons by 2002 while consumption was 776 million tons in 1998 and increased to 840 million tons in 2002 as shown in Table 2. The figures show a production increase of 7.4% during the period while consumption increased by 8.2%. Once again production appears to be on the decline in North and Central America. Though South America registered the highest production increase percent-wise, in absolute terms Asia registered the highest production and consumption.

Specialty paper grades are high value products produced for a restricted market and a specific purpose. Small specialty mills normally produce special grades of these papers. Examples of specialty papers include those used for currency/security, cigarette, dielectric, filtration, fine printing, bible papers, tea and vacuum bags, wet-laid non-wovens, laminating substrates, fruit wrap, anti-static and water repellent papers, etc. Sisal pulp (bleached and unbleached) is ideally suited for use in dielectric papers, plug wrap, vacuum and tea bags, filtration papers, laminating substrates, wet laid non-wovens. Bleached sisal pulp is suitable for cigarette papers.

Production and trade in specialty pulp and paper is enclosed in secrecy. It is difficult to obtain exact data and future market potential for specialty pulp is thus based on extrapolation of past production and consumption. The estimated potential market for sisal specialty pulp based on the market study undertaken by Sevenhuijsen Associates of the Netherlands and projections by Mrs. Rosely M. V. Assumpcao, a pulp and paper consultant for the project are shown in the tables hereunder presented. Total specialty pulp requirements for specialty grade papers are shown below and include all types of pulps going into specialty use e.g. abaca, hemp, jute, cotton, wood and sisal.

**Table 3: Estimated World Specialty Paper and Pulp Production ('000 tons)**

| Production | | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|---|
| **Total Paper** | World | 217,020 | 260,320 | 301,080 | 352,000 | 408,490 |
| | China | 13,720 | 24,000 | 29,550 | 44,620 | 62,440 |
| | World – China | 203,300 | 236,390 | 271,530 | 307,380 | 346,050 |
| **Specialty Paper** | % Specialty paper | 1.33 | 1.33 | 1.33 | 1.33 | 1.33 |
| | World | 2,883 | 3,459 | 4,000 | 4,677 | 5,427 |
| | China | 182 | 319 | 393 | 593 | 830 |
| | World-China | 2,701 | 3,141 | 3,607 | 4,084 | 4,597 |
| **Specialty Pulp** | World | 110 | | | | |
| | % Specialty pulp | 4.1 | 4.5 | 5.0 | 5.5 | 5.5 |
| | Specialty pulp | 110 | 141 | 180 | 225 | 253 |
| **Specialty Pulp Ex-China** | % Specialty pulp | 10 | 10 | 10 | 10 | 10 |
| | Specialty pulp | 18 | 32 | 39 | 59 | 83 |
| **World Total** | % Specialty pulp | 4.4 | 5.0 | 5.5 | 6.1 | 6.2 |
| | Specialty pulp | 128 | 173 | 220 | 284 | 336 |

The breakdown of world specialty pulp production by type is given in Table 4 below.

**Table 4: Estimated Demand for Specialty Pulp by Type of Pulp ('000 tons)**

| Year | 1990 | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| **World Specialty Pulp Demand** | **128.23** | **173.16** | **219.63** | **283.88** | **335.82** |
| Abaca | 25.00 | 27.83 | 29.43 | 31.82 | 33.81 |
| Flax, Hemp, Jute | 38.47 | 51.95 | 65.89 | 85.16 | 100.75 |
| Cotton | 32.06 | 43.29 | 54.91 | 70.97 | 83.95 |
| Wood | 16.35 | 25.05 | 34.70 | 47.96 | 58.65 |
| Sisal | 16.35 | 25.05 | 34.70 | 47.96 | 58.65 |

Bleached Kraft Softwood (BKS) is the main pulp used for reinforcement and estimated world consumption for the period 1995 to 2010 is shown in Table 5 below.

**Table 5: Bleached Softwood Consumption per Region (million tons)**

| Region | | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|---|
| Europe (EU) | | 7.1 | 7.3 | 7.6 | 7.9 |
| North America (NA) | | 3.9 | 4.1 | 3.8 | 3.6 |
| Latin America | | 0.7 | 0.9 | 1.3 | 1.9 |
| Asia (A) | China | 0.6 | 1.0 | 2.0 | 3.2 |
| | Japan | 1.7 | 1.9 | 2.0 | 2.1 |
| | Other Asia | 1.3 | 2.2 | 3.2 | 4.4 |
| | Sub-total Asia | 3.6 | 5.1 | 7.2 | 9.7 |
| Australasia (AT) | | 0.2 | 0.4 | 0.4 | 0.5 |
| **Total** | | **15.6** | **17.7** | **20.3** | **23.5** |

Bleached softwood consumption by grades is shown in Table 6 below.

**Table 6: Bleached Softwood Consumption per Grade (million tons)**

| Grade | 1995 | 2000 | 2005 | 2010 |
|---|---|---|---|---|
| Coated wood free | 2.1 | 2.3 | 2.7 | 3.2 |
| Uncoated wood free | 3.1 | 3.7 | 4.2 | 4.7 |
| Coated mechanical | 2.5 | 2.5 | 2.5 | 2.8 |
| Uncoated mechanical | 1.1 | 1.2 | 1.4 | 1.8 |
| Tissue | 1.6 | 1.8 | 2.0 | 1.9 |
| Board | 2.7 | 3.1 | 3.6 | 4.3 |
| Newsprint | 0.7 | 1.0 | 1.3 | 1.7 |
| Other papers | 1.8 | 2.1 | 2.6 | 3.1 |
| **Total** | **15.6** | **17.7** | **20.3** | **23.5** |

### *3.2 Demand size*

Based on interviews conducted in July and August 2004 by Mr. Salum Shamte with a number of pulp mill officials in Europe and Tanzania and with industry experts, the current market for specialty pulp is estimated at around 250,000 tons growing at 5-6% per annum in the last four years. This includes all types of pulps going into specialty uses such as abaca, flax, hemp, jute, cotton, wood pulp and sisal. Out of these, the current production of sisal pulp is around 45,000 tons growing at the same rate. The fibre required to produce this pulp is around 90,000 tons.

Reinforcement pulp for commodity paper grades is another potential market of sisal pulp. Sisal pulp has superior reinforcement qualities than softwood pulp. The market price of BKS is between US$ 550 – 580 per ADMT while that of sisal pulp is US$ 1,600 per ADMT. The current market for BKS is around 15 million ADMT per annum growing at 9% in the last 7 years. The market potential for sisal reinforcement pulp is very high but is prohibited by the price and reliable availability of large quantities of fibre. Pulp mills have indicated willingness to pay a premium for sisal fibre of 12% over the BKS price.

It is difficult for sisal pulp to capture a sizable share in the huge reinforcement pulp market because of price considerations. A large portion (40%) of sisal pulp production cost is the cost of raw fibre. The cost of sisal pulpable fibre needs to be reduced drastically if sisal pulp is intended to compete effectively with softwood pulp. This is possible by developing suitable new varieties, improved agronomic practices and better fibre extraction technologies.

## *3.3 Marketing Concept, Sales and Marketing Budget*

### 3.3.1 Description of the marketing concept, selected targets and strategies

The main strategy of the project is to reduce pulpable sisal fibre production cost in order to gain cost leadership against competitors to be able to penetrate the specialty and reinforcement pulp markets. The market study has revealed that target groups i.e. pulp manufacturers are generally price-oriented. BKS, used as the main reinforcement pulp, is by far cheaper than sisal pulp, which has superior reinforcement properties. However, the specialty pulp market is quality-oriented. Sisal properties for porosity, tensile and tear are lower than for abaca but sisal prices are about 60% lower than abaca. Some manufacturers offer premium prices for sisal to ensure steady and reliable sisal fibre supply.

Results from trials in development of new sisal varieties, enhancement of agricultural practices and application of better fibre extraction technologies have registered modest achievements in terms of overall cost reduction in sisal fibre production. Further improvements can be obtained from continued research and development in those areas. Investment in small pulp mills is currently possible if niche specialty markets are targeted. Profitable mills can be as small as 5 ADMT per day. Investments in reinforcement pulp production will be larger as potential buyers require larger quantities of supply and higher economies of scale to be able to reduce the cost.

Katani Limited at the beginning targets to produce sisal fibre for the specialty paper and pulp market rather than the reinforcement paper and pulp market because of the fiercer competition. Moreover, prices in the specialty paper market are significantly higher than in the reinforcement pulp market. The competition strategy is thus to gain market share at the expense of other crop fibres mainly abaca, jute, hemp and flax pulps by focusing on pulp properties for which sisal pulp has an edge such as porosity. Worldwide demand of sisal fibre for pulp production is presently around 90,000 tons per year. It is possible to capture at least 5% of this market (4,500 ADMT per year) taking into consideration the high quality of staple fibre to be produced.

Due to technical considerations, it is planned to produce 4,536 ADMT of pulpable sisal fibre per year at steady state. The fibre will be sold to local and Western European pulp mills. Preliminary contacts and informal discussions made with Kibo Pulp and Paperboard Mill in Tanzania indicate the mill can buy more than 50% of the sisal fibre produced provided supply is steady and reliable.

### 3.3.2 Competition

As observed earlier, other crop pulps compete with sisal pulp in the specialty and reinforcement pulp markets. The main competitors of sisal in specialty pulp are bleached and unbleached abaca pulps due to their strength, viscosity and porosity; flax pulp for currency, security and cigarette papers; and hemp and jute pulps for cigarette papers. Comparisons between sisal and abaca specialty pulp properties (of hand sheets at 40 g/m$^2$) are illustrated in figures 1, 2 and 3.

**Figure 1: Breaking Length Vs Refining Time – Sisal and Abaca**

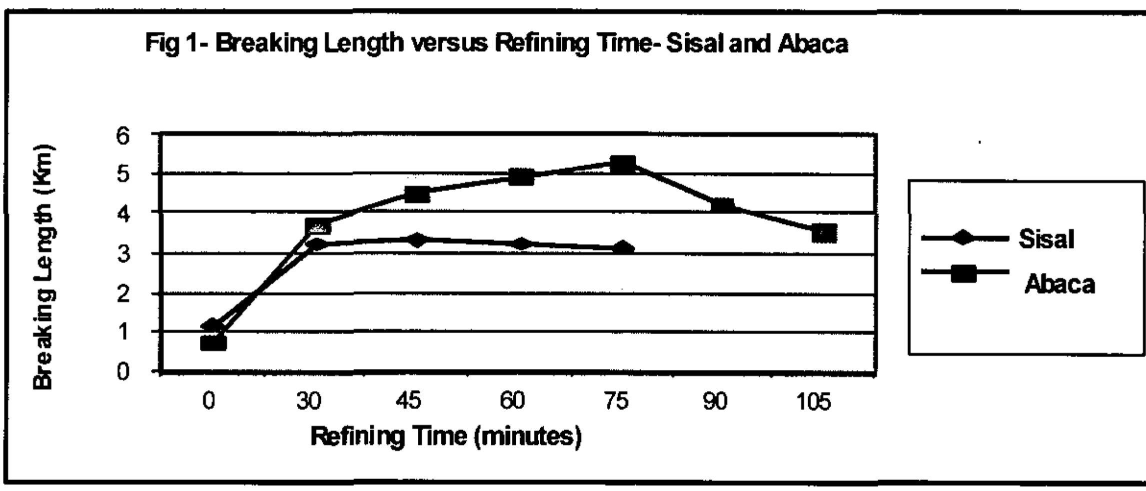



**Figure 2: Tear Index Vs Refining Time – Sisal and Abaca**

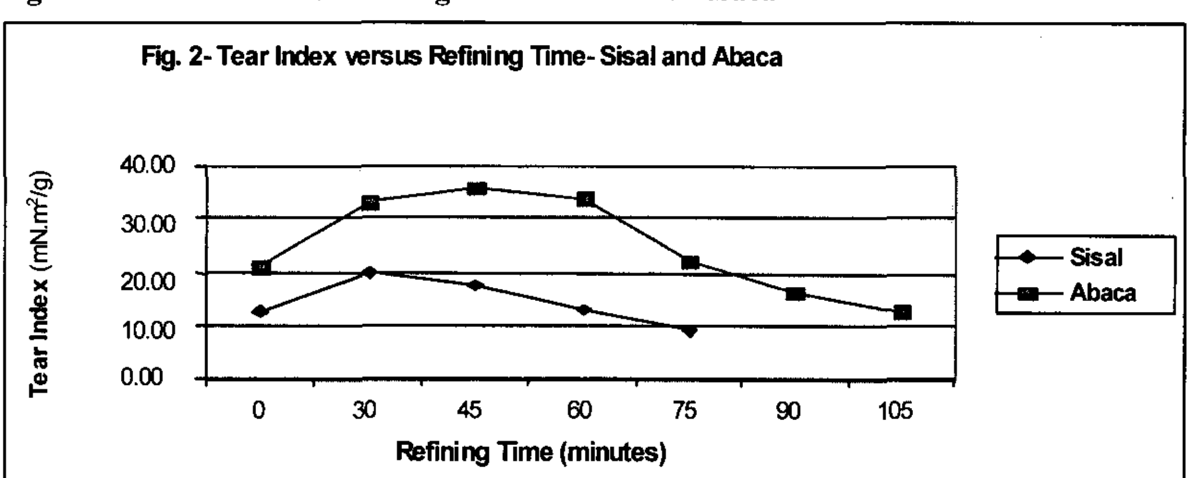
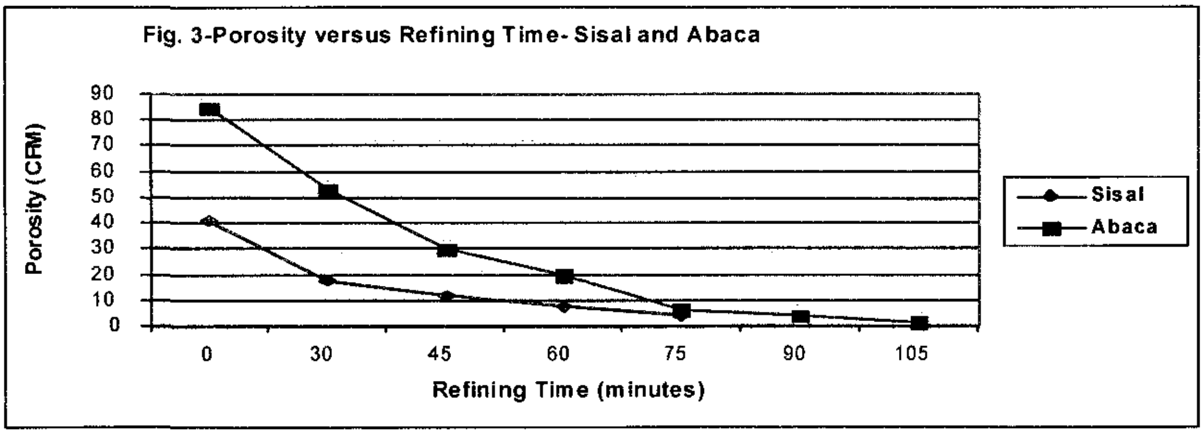


**Figure 3: Porosity Vs Refining Time – Sisal and Abaca**




It is evident that abaca pulp has better properties than sisal pulp. However, the market price for abaca pulp ranges between US$ 2,400 – 2,800 per ADMT while sisal pulp prices range between US$ 1,500 – 1,700 per ADMT.

Reinforcement pulp is used in the paper furnish to improve the wet web and the final common grade paper properties. This grade of pulp is used in printing and tissue paper furnishes containing mechanical and hardwood pulps as well as recycled fibres that have poor bonding properties. At present, the main reinforcement pulp is BKS.

Important reinforcement pulp properties are:
(a) Aspect ratio i.e. the ratio between fibre length and fibre width;
(b) The relation of tear and tensile index or breaking length at the same freeness level.
The aspect ratio of sisal and selected softwood commercial pulps are shown in Table 7 below.

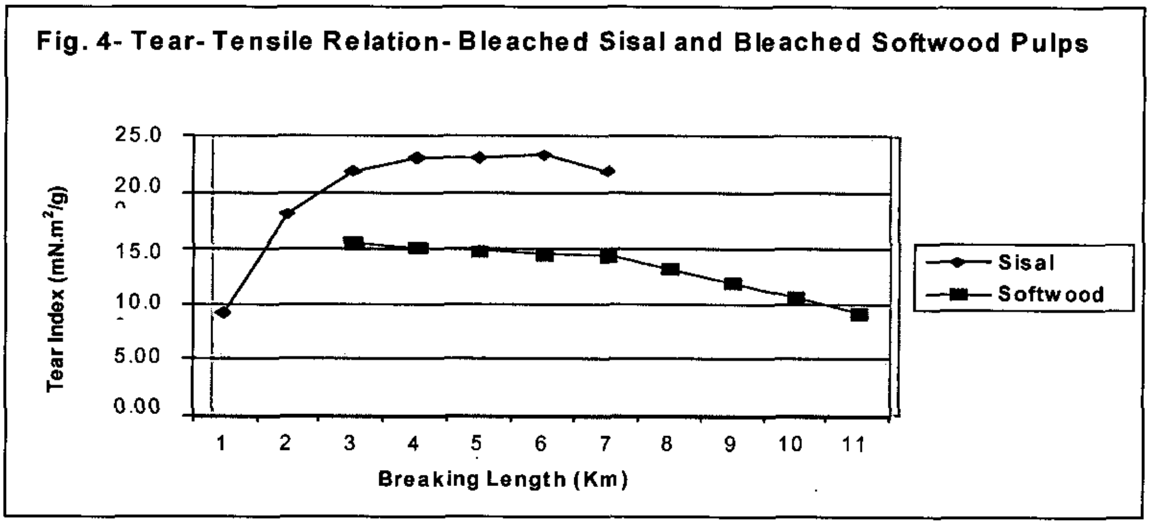
**Table 7: Aspect Ratio of Sisal and Selected Softwood Pulps**

| Fibre | Length (L) mm | Width (W) micron | Aspect ratio (L:W) |
|---|---|---|---|
| Sisal | 3.30 | 20 | 165:1 |
| Sisal | 3.03 | 17 | 178:1 |
| Western Hemlock | 3.35 | 35 | 96:1 |
| Douglas Fir | 4.00 | 40 | 100:1 |
| Hesperaloe | 3.60 | 15 | 240:1 |

Compared with softwood pulps, sisal pulp demonstrates better aspect ratio, indicating better reinforcement characteristics.

The relation between tear and tensile indexes of sisal and softwood pulps is shown in figure 4.

**Figure 4: Tear-Tensile Relation; Bleached Sisal and Bleached Softwood Pulps**




The figure above shows that sisal has better tear index than softwood pulp at the same breaking length. Coupled with better aspect ratio, it is clear that sisal pulp has good reinforcement capabilities and can effectively compete with softwood pulp in terms of quality.

### 3.3.3 Location of Markets and Target Groups

Major consumers of specialty pulp are Europe, North America and Japan. China, India and South East Asia are becoming increasingly important both as major markets and consumers of pulp. Some mills in Europe are contemplating relocation to areas of sources of fibre and where the costs of energy and labour are lower than in Europe.

More intensive market surveys in China, South East Asia, Middle East and Africa are needed, as there is scanty published market information. The demand for paper products in these emerging markets are expanding at a faster rate than developed European and North American markets.

A number of contacts were established with potential customers for sisal pulpable fibre and sisal pulp in Europe. There is a demand for sisal pulpable fibre, sisal pulp and paper products. Contacts were also established with pulping equipment suppliers for future pulping operations.

### 3.3.4 Sales Program

The total volume of sales will reach a maximum of 4,567 ADMT per annum in year 2014. The assumed selling price is US$ 600 FOB Tanga port per ADMT throughout the project life. The sales program is equivalent to production less provision for one-day stock of leaves and 14-days stock of sisal fibre produced.

### 3.3.5 Annual Sales Revenues

Annual sales are expected to increase as production of sisal fibre increases. Sales revenue from the project is expected to rise from US$ 1,151,131 in the first production year to US$ 4,232,392 at the end of the project. The assumed price excludes local taxes, levies and commissions. Details of annual sales for the 3-hammer mill scenario are shown in Table 8 below.

**Table 8: Projected Staple Sisal Fibre Production and Sales (Units: ADMT, Currency: US$)**

| | Local Sales | | | Export Sales | | | Total Sales | | |
|---|---|---|---|---|---|---|---|---|---|
| **Yr.** | **Units** | **Price** | **Revenue** | **Units** | **Price** | **Revenue** | **Units** | **Revenue (excl Inflation)** | **Revenue (incl. Inflation)** |
| 2006 | - | - | | - | - | - | | - | |
| 2007 | - | - | | - | - | - | | - | |
| 2008 | 818.00 | 625 | 511,250.00 | 818.00 | 600 | 490,800.00 | 1,636 | 1,002,050.00 | 1,151,130.67 |
| 2009 | 1,132.00 | 625 | 707,500.00 | 1,132.00 | 600 | 679,200.00 | 2,264 | 1,386,700.00 | 1,656,727.52 |
| 2010 | 1,528.00 | 625 | 955,000.00 | 1,528.00 | 600 | 916,800.00 | 3,056 | 1,871,800.00 | 2,325,741.03 |
| 2011 | 1,939.50 | 625 | 1,212,187.50 | 1,939.50 | 600 | 1,163,700.00 | 3,879 | 2,375,887.50 | 3,070,160.81 |
| 2012 | 2,053.00 | 625 | 1,283,125.00 | 2,053.00 | 600 | 1,231,800.00 | 4,106 | 2,514,925.00 | 3,379,820.44 |
| 2013 | 2,166.50 | 625 | 1,354,062.50 | 2,166.50 | 600 | 1,299,900.00 | 4,333 | 2,653,962.50 | 3,709,340.59 |
| 2014 | 2,240.50 | 625 | 1,400,312.50 | 2,240.50 | 600 | 1,344,300.00 | 4,481 | 2,744,612.50 | 3,989,480.12 |
| 2015 | 2,285.50 | 625 | 1,428,437.50 | 2,285.50 | 600 | 1,371,300.00 | 4,571 | 2,799,737.50 | 4,232,392.36 |
| **Total** | **14,163.00** | | **8,851,875.00** | **14,163.00** | | **8,497,800.00** | **28,326** | **17,349,675,00** | **23,514,793.54** |

### 3.3.6 Annual Costs of Sales Promotion and Marketing

Sales promotion and marketing costs are estimated at 3% of the sisal fibre sales during the production period. US$ 25,000 will be spent annually on developing markets in the second and third year of the construction period. Of the allotted amount for sales promotion and marketing, 80% will go towards advertising, 10% on public relations and 10% on personal selling efforts.

## *3.4 Production Programme*

### 3.4.1 Products

Sisal fibre will be the main product produced. The maximum production level is based on the technical capacity of the FEX plant. Production includes stock required during the production period. Sisal fibres are taken as 4.0% by weight of fresh sisal leaves in the fibre extraction process.

Production starts in year 2008. Production in the 3-hammer mill scenario starts with 1,700 ADMT in 2008 gradually increasing to 4,575 ADMT by year 2015 while in the 2-hammer mill scenario production increases from 850 ADMT in 2008 to 2,287 ADMT by 2015. The

3-hammer mill scenario produces 28,505 ADMT during the life of the project while the 2-hammer mill scenario produces 14,251 ADMT as per Table 9 below.

**Table 9: Production**

| Year | 2-Hammer Mills (TONS) | 3-Hammer Mills (TONS) |
|---|---|---|
| 2008 | 850 | 1,700 |
| 2009 | 1,144 | 2,288 |
| 2010 | 1,543 | 3,087 |
| 2011 | 1,956 | 3,911 |
| 2012 | 2,057 | 4,115 |
| 2013 | 2,170 | 4,342 |
| 2014 | 2,244 | 4,487 |
| 2015 | 2,287 | 4,575 |
| **Total** | **14,251** | **28,505** |

### 3.4.2 By-products from the Waste

The fibre extraction process essentially separates the outer green skin of the sisal leaf from the fibre and the binding materials between fibres within the sisal leaf. After the fibre is extracted from the leaf, the remaining material is very suitable for biogas production or as fertilizer.

Liquid and solid effluents from the plant are over 90% of the total output at the end of the extraction process. These form the main source of waste at the plant. The waste contains chemical extracts, water and sisal mucilage. This waste has very few short fibres compared to the conventional decortication process and would be a perfect substrate for the biogas plant as no further separation process would be required.

Analysis of sisal effluent done by the Chemistry Department at the University of Dar-es-Salaam in February 2005 produced the following results:

**Table 10: Analysis Hammer Mill and Decorticator Waste**

| Parameter | Decorticator Effluent | Hammer Mill Effluent |
|---|---|---|
| PH | 4.9 | 5.1 |
| Viscosity (cp) | 0.928 | 0.945 |
| Conductivity (mS/cm) | 18.75 | 5.29 |
| Redox Potential (V vs. SHE) | 0.81 | 0.57 |
| Density (g/cm$^3$) | 1.0102 | 1.0039 |
| BOD5 (mg/l) | 8.77 | 254.38 |
| COD (g/l) | 7.26 | 13.54 |
| Suspended Solids (g/l) | 0.541 | 0.612 |
| Total Nitrogen (mg/l) | 117.82 | 273.68 |
| Nitrogen as $NH_4$-N (mg/l) | 14.2 | 67.47 |
| Nitrites (mg/l) | 0.061 | 0.164 |
| Nitrates | 21.95 | 6.5 |
| Total Phosphorus (mg/l) | 27.45 | 90.92 |
| Total Organic Carbon (g/l) | 1.81 | 3.02 |
| Sodium (mg/l) | 965.13 | 69.41 |
| Potassium (mg/l) | 106.32 | 340.22 |
| Magnesium (mg/l) | 752.01 | 351.73 |
| Calcium (mg/l) | 557.38 | 351.01 |
| Iron (mg/l) | 4.64 | 12.53 |
| Manganese (mg/l) | 20.14 | 0.82 |
| Copper (mg/l) | 0.11 | 0.14 |
| Zinc (mg/l) | 0.68 | 1.85 |
| Sugars (g/l) | 9.19 | 13.15 |
| Total Organic Acids (g/l) | 6.26 | 1.31 |
| Amino Acids (g/l) | 3.63 | 7.42 |

**Table 11: Composition of Hammer Mill and Decorticator Waste (%)**

| Parameter | Decorticator Effluent | Hammer Mill Effluent |
|---|---|---|
| Dry Matter | 2.61 | 2.24 |
| Sugars | 0.91 | 1.31 |
| Ash Content | 1.26 | 0.47 |
| Organic Acids | 0.62 | 0.13 |
| Total Nitrogen | 0.01 | 0.03 |
| Total Phosphorus | <0.01 | 0.01 |

The results show that hammer mill waste has higher quantities of sugar, less ash content, lower levels of organic acids, three times the total nitrogen and higher levels of phosphorus, total organic carbon, potassium and zinc. The carbon content is very important for biogas production. The higher the content the more biogas will be produced.

## 4.0 MATERIAL INPUTS

### *4.1 Raw Materials*

All main raw materials required for the fibre extraction process are available locally. These are fresh sisal leaves and water. Sisal leaves will be procured from smallholder and outgrower sisal at Hale Estate. The fields established to feed the fibre extraction plant will apply the CEPS system of cultivation of sisal applied with fertilizer at a density of 6,400 plants per hectare. The maximum plant capacity in the 3-hammer mill scenario is to process 20 tons of green leaf per hour or around 140 tons in a 7-hour shift while in the 2-hammer mill scenario 10 tons would be required per hour equivalent to 70 tons in a 7-hour shift. The 3-hammer mill scenario requires about 27 cubic metres of water per hour or 189 cubic metres per 7-hour shift. Water will be drawn from the Pangani River through the diversion channel established at the present mill site. Supply of sisal leaf metres to the mill are shown in Table 12 for each scenario.

**Table 12: Sisal Leaf Metres Supplied by Smallholders and Outgrowers**

| Year | 2-Hammer Mills | 3-Hammer Mills |
|---|---:|---:|
| 2008 | 27,262 | 54,524 |
| 2009 | 32,618 | 65,236 |
| 2010 | 39,131 | 78,262 |
| 2011 | 45,153 | 90,305 |
| 2012 | 49,058 | 98,116 |
| 2013 | 52,462 | 104,924 |
| 2014 | 54,862 | 109,724 |
| 2015 | 56,476 | 112,953 |
| **Total** | **357,022** | **714,044** |

### *4.2 Factory Supplies*

Factory supplies required by the project would include oils, greases, baling ropes, Hessian cloth for baling and biogas for the dryer. These will be procured locally.

### *4.3 Utilities*

Electricity will be supplied either from TANESCO or from the biogas plant. For the three-hammer mills a transformer with minimum power output of 500 KVA will be required. The hammer mill site has an 11 KVA line; a 33 KVA line and a 220 KVA line passing overhead.

A logic power and control circuit design will allow switching and shut down of the mills in sequence so as not to overload the transformer. Power consumption is estimated at 300 kW hours per ton on 150 KVA units per month in the 2-hammer mill scenario and 500 kW hours per ton on 250 KVA units per month in the 3-hammer mill scenario. The price per kWh is based on present TANESCO rates of Tsh. 63 while the KVA is charged Tsh. 6,900 per unit.

A sales tax of 20% is additionally charged together with a service charge of Tsh. 6,300 per month.

Water supply is required to facilitate reduction of parenchyma in the sisal fibre during the first and second pass process. During the optimization stage the washing system developed by TATC will be evaluated for its capability in reducing the parenchyma in the fibre. Daily water consumption will amount to 112 cubic meters of water per 7-hour shift. Payment for water rights on an annual basis will cost around US$ 175.

## 5.0 LOCATION, SITE AND ENVIRONMENT

### *5.1 Location*

Due to the existing establishment and corporate structure of Katani Ltd., location of the FEX plant had to be limited to one of the 5 estates it owns. Conditions considered for the selection of both location and site of the plant were, proximity to raw materials (sisal leaf supply), availability of plot for the plant, and proximity to Tanga port. Of all the estates owned by Katani, Hale estate is the nearest to Tanga port. Hale estate is located 70 km from Tanga. Of this distance, 65 km is tarmac road along the Tanga-Dar highway. The selected site for the FEX plant is Hale section of Hale estate, where the first hammer mill was installed. The site has the required land is also ideal for sisal waste disposal.

### *5.2 Preliminary Environmental Impact Assessment*

Investigation on environmental impact assessment was done recently. The waste produced is acidic but decomposes naturally and within a few days (less than a week) becomes non-toxic. It is estimated that about 45 tons per hour of parenchyma and wastewater would be produced from the FEX plant. This is a large amount of waste and may pollute water sources if left untreated. Three oxidation ponds are therefore planned to treat wastewater from estates. After treatment, the solid dried product would be used as fertilizer on the estates and the resultant water used for irrigation on the nurseries or field. Each oxidation pond will cost US$ 8,000.

A pilot demonstration biogas plant to convert the sisal waste into biogas is soon to be implemented to produce biogas for domestic use and electricity generation through CFC, UNIDO and counterpart financial contributions. It is anticipated that, in the long run, biogas plants will be installed in all sisal estates to enhance estate profitability by selling surplus electricity to the National Grid and using the by-products as fertilizer for increased productivity of the land. The biogas plants will replace oxidation ponds for treatment of wastewater.

## 6.0 PROJECT ENGINEERING

### *6.1 Determination of Plant Capacity*

The proposed annual plant capacity was determined primarily on the basis of the market volumes of 2% of the specialty sisal pulp market in the world. Another important consideration was green leaf availability. An investment in 1,890 hectares is capable of producing the green leaf required to produce 4,571 tons of pulpable sisal fibre for sale. This will require supply of green leaf of around 140 tons per day for a single 7-hour-shift per day, 280 tons on two shifts and 420 tons on three shifts.

### *6.2 Preliminary Determination of Project Scope*

Commercial production of pulpable sisal fibre necessitated the development of new technology. The technology was expected to produce fibre from the leaf and the bole to increase the yield of fibre per unit area and to recover more efficiently short fibre from the leaf butt end and the bole not extracted in the conventional decorticators. The new technologies evaluated were the roller crusher and hammer mill or a combination of the two. Katani Limited was contracted in 2004 by UNIDO under project FC/RAF/96/001/21-13-3 to:

(i) Evaluate the process of hammer milling and crushing as two potential technologies for extracting efficiently pulpable export fibre from sisal whole-plant, leaves and boles;

(ii) Determine the technology, basic unit operations and technical cost parameters for the FEX demonstration plant for Hale Estate.

Several experiments were conducted on water consumption, parenchyma reduction, energy, operational approach, and physical state of inputs and final quality of the produced fibre. Experiments revealed that fibres from the roller crusher were often damaged due to carrying over and excessive crushing. The crushing process does not adequately reduce parenchyma in the fibre unless several washing stages are instituted. After several washing stages the parenchyma content was reduced to around 10%, but a large amount of the fibre was lost with the parenchyma. The fibre loss was estimated to be 10% to 20% of the total fibre. The process used large amounts of water. About 1.2 cubic metres per kg of dry fibre or about 39 litres of water per kg of fresh sisal chips was consumed.

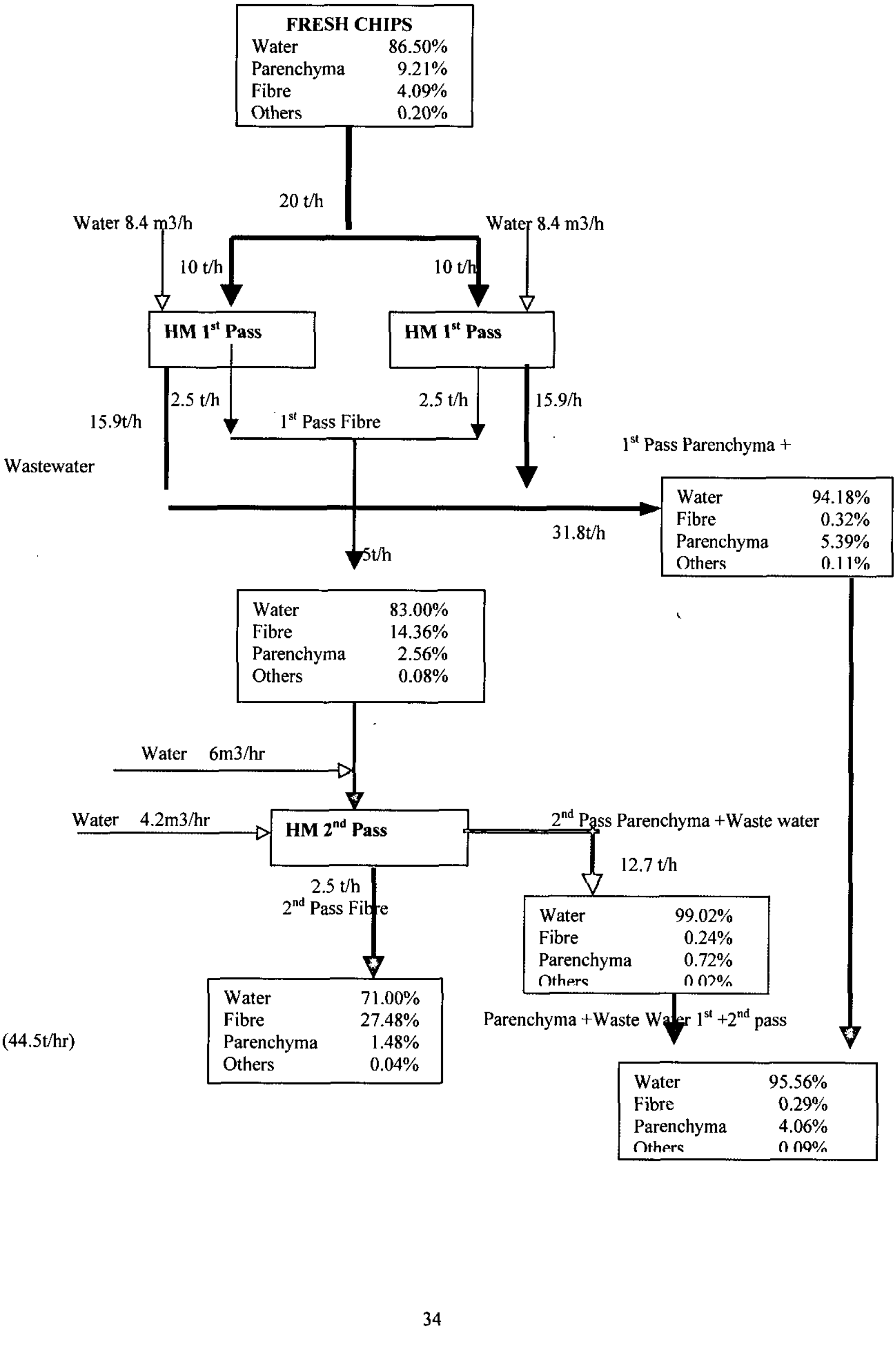
Optimal results were obtained by using the hammer mill system, which generated minimum fibre losses and parenchyma content of about 5% and used only 0.032 cubic metres of water per kg of dry fibre. Sisal fibre with parenchyma content exceeding 5% consumes more chemicals during pulping and produces poor quality pulp.

### *6.3 Technology and Equipment*

The hammer mill technology was first adapted for sisal in Brazil. Improved drawings for such a plant were procured from Brazil and used in Tanzania to manufacture the first hammer mill with some modifications. The feed conveyor and steel structure were later added to the system by TATC, the manufacturers of the mill. The same manufacturer will produce additional equipment for the FEX demonstration plant. These will include more efficient feeding, chipping, washing and parenchyma removal to improve the quality of the sisal fibre.

The technology for the FEX plant will consist of two hammer mills simultaneously performing the 1st pass. At this stage, 20 tons of fresh sisal chips (10 tons through each mill) will be processed to produce sisal fibre using water supplied at the rate of 16.8 $m^3$ per hour (8.4 $m^3$ per hour per mill). The parenchyma content of the sisal fibre will be around 15% of the throughput weight. A third hammer mill will perform the 2nd pass using water injected at a rate of 10.2 cubic metres per hour. The final output will be wet sisal fibre with moisture content of 71% dried to a moisture content of around 10% mechanically using a biogas dryer. The output of the sisal fibre after drying will be around 800 kg per hour with parenchyma content of about 5%. A diagrammatic outline of the technology and process is presented in Figure 5 below.

**Figure 5: Material Flow for the 3-Hammer Mill FEX Plant**



## 6.4 Technology description and forecast

To produce sisal fibre for pulp production, it was found necessary to change the fibre extraction technique from traditional decortication to the hammer mill technology. The new fibre extraction technology still requires cutting of leaves and leaf transport. At the mill site leaves will be fed into a chipper, chipped into 7cm length and thereafter hammer milled with resulting wet fibre dried before baling and selling. The new technology was intended to produce fibre from the leaf and the bole to increase yield of fibre per unit area. The technology was also expected to recover more efficiently the short fibres from the leaf butt ends, not done in conventional decorticators. During trials, the bole fibre was efficiently extracted by the hammer mill but could not be pulped together with leaf fibres, as it required different pulping conditions. Bole fibres take longer to pulp and consume more chemicals.

The new technology is not suitable for traditional products such as cordage but can be used to produce fibre for composites in automobiles and construction industry.

## 6.5 Proposed FEX System

The FEX plant system comprises of 7 main components. A brief description of each component is given hereunder. Detailed technical specifications of the equipment are in annex 1.

(a) Sisal Chipping

The system consists of a 12.5-ton per hour sisal chipper, inclined plate, chipper feed conveyor and feed trailer. Haulage of sisal leaves will be done using conventional sisal trailers from the field to the chip yard. Sisal leaves will be chipped to sizes ranging between 40 and 100 mm long using chippers adopted from silage cutters. The chips will be fed to an inclined plate fitted and thereafter to a chipper feed conveyor. The chipper feed conveyor will discharge chips to a feed trailer, which will in turn feed the supply conveyor at the mill.

(b) Mill Feeding System

The mill feeding system has a transport conveyor, helicoidal conveyors and dosing feeder. Sisal chips from the flat bed supply conveyor are discharged to the chips transport conveyor. The chips are then fed to the helicoidal conveyor $\phi$ 420mm. This conveyor has two chip output pots for feeding the two hammer mills. Chips from the conveyors will be discharged to two dosing feeders, which regulate charges to the two helicoidal conveyors $\phi$ 280 mm. Sisal chips from the helicoidal conveyors $\phi$ 280 mm are then fed to the hammer mills through supply chutes.

(c) Vertical Mills

The vertical mills will comprise of three milling machines. Two of the mills will be used for the first stage fibre extraction, and the third mill for the second stage extraction. During the first stage, sisal chips from the supply chutes will be milled to separate sisal fibre and parenchyma. Semi clean fibre will be produced and discharged while at the same time forcing the parenchyma through the screen holes of the mills and scraped to the discharge spouts directing the materials out of the mill. The semi-clean fibre from the first stage will be discharged to the second stage mill for second pass processing using the collector and discharge conveyors.

(d) Washing

The fibre will be washed during fibre extraction by injecting water into the hammer mills. In the first stage, 8.4 $m^3$ of water will be injected into the hammer mill through the screen. In the second pass, 6 $m^3$ of water will be mixed with the fibre in the screw conveyor $\phi$ 280 mm, and 4.2 cubic metres will be injected through the hammer mill screen.

(e) Drying and Baling System

The fibre drying process will consist of a charge conveyor, squeezer, gas dryer and baling press. This is the last stage of the FEX process where wet fibres from the charge conveyor are passed through the squeezer and then through the dryer for further water removal before baling in a hydraulic press.

(f) Support Structure

The structure is designed to support two mills, the mill feeding system and provide walkways to facilitate plant maintenance procedures. The systems mounted on the structure include helicoidal conveyors and dosing feeders.

### *6.6 Plant Layout*

A schematic layout of the plant showing structural arrangement of equipment components and auxiliary parts is shown on annex 2. The diagram shown is not to scale. Space provided for the plant together with civil works is estimated to be 6 hectares.

### *6.7 FEX System Investment Cost*

The total fixed investment costs for the 3-hammer mill FEX plant are projected at US$ 2,834,850 while total fixed investment costs for the 2-hammer mill FEX plant are US$ 1,795,940. Total investment costs for the 3-hammer mill FEX plant are US$ 3,322,110 while the 2-hammer mill FEX plant costs US$ 2,079,340 including capitalized interest during the construction period and required working capital. Most of the parts for the FEX system including components and sub-components will be manufactured locally but some items will be procured from abroad.

**Table 13: Total investment Costs for the two FEX Systems**

| ITEM | 3-HAMMER MILLS | 2-HAMMER MILLS |
|---|---|---|
| ***LAND:*** | | |
| ***Project Land*** | 100,000 | 50,000 |
| ***SUB-TOTAL LAND COST*** | **100,000** | **50,000** |
| ***NURSERY PLANTING COST:*** | | |
| ***Land Preparation*** | 69,300 | 34,650 |
| ***Nursery Planting*** | 22,680 | 11,340 |
| ***Nursery Maintenance*** | 29,610 | 14,805 |
| ***Soil Analysis*** | 12,600 | 6,300 |
| ***SUB-TOTAL NURSERY PLANTING*** | **134,190** | **67,095** |
| ***AGRICULTURAL MACHINERY:*** | | |
| ***Leaf Loader*** | 45,000 | 45,000 |
| ***Wheel Tractors 85 HP 4WD*** | 363,000 | 231,000 |
| ***Wheel Tractors Holland 55/56*** | 145,200 | 96,800 |
| ***Disc Harrow 20 Discs*** | 7,700 | 7,700 |
| ***Rotary Slasher & Gyramower*** | 5,500 | 5,500 |
| ***Motorized Knapsack Sprayer*** | 8,800 | 8,800 |
| ***Amazon Fertilizer Spreader*** | 9,900 | 9,900 |
| ***Furrow Opener*** | 6,000 | 6,000 |
| ***Transplanter*** | 12,000 | 12,000 |
| ***Cultivator/Fertilizer Side Dresser*** | 12,000 | 12,000 |
| ***SUB-TOTAL AGRICULTURAL MACHINERY*** | **615,100** | **434,700** |
| ***LEAF TRANSPORT:*** | | |
| ***Trailer 7 Ton 2 Axles*** | 115,500 | 57,750 |
| ***SUB-TOTAL*** | **115,500** | **57,750** |
| ***PERSONNEL TRANSPORT:*** | | |
| ***4WD Pickup*** | 55,000 | 55,000 |
| ***Service Vehicle*** | 0 | 0 |
| ***Motorcycles*** | 13,200 | 13,200 |
| ***SUB-TOTAL VEHICLES*** | **68,200** | **68,200** |
| ***EQUIPMENT/STUDIES:*** | | |
| ***Computer, Printer & Software*** | 8,800 | 8,800 |
| ***Laboratory Equipment*** | 183,725 | 183,725 |
| ***Office Furniture*** | 4,400 | 4,400 |
| ***Project Implementation*** | 74,610 | 74,610 |
| ***Market Studies*** | 50,000 | 50,000 |
| ***SUB-TOTAL EQUIPMENT/STUDIES*** | **321,535** | **321,535** |
| ***MILL PROCESSING MACHINERY:*** | | |
| ***Dryer*** | 132,000 | 55,000 |
| ***Electricity Meter*** | 27,500 | 27,500 |
| ***Baling Press*** | 39,600 | 19,800 |
| ***Water Jet System*** | 1,430 | 1,430 |
| ***Squeezer*** | 13,530 | 13,530 |
| ***Carding Machine*** | 7,700 | 7,700 |
| ***1st Hammer Mill*** | 82,016 | 82,016 |
| ***2nd Hammer Mill*** | 73,040 | 73,040 |
| ***3rd Hammer Mill*** | 73,040 | 0 |
| ***Chipper 12.5 Tons/Hr Capacity*** | 58,049 | 35,609 |

| | | |
|---|---|---|
| *Collector Conveyor* | 14,080 | 14,080 |
| *Discharge Conveyor* | 36,080 | 18,040 |
| *Inclined Chipper Feeding Plate* | 4,840 | 2,420 |
| *Chipper Feed Conveyor* | 13,200 | 6,600 |
| *Feed Trailer(4.8mx2mx1m)* | 13,750 | 5,500 |
| *Dosing Feeder* | 12,870 | 0 |
| *Screw Conveyor 280* | 17,930 | 0 |
| *Belt Conveyor Set 1x2m, 1x6m, 2x8m* | 81,400 | 24,420 |
| *Tool set & Chain Block* | 2,200 | 2,200 |
| *SUB-TOTAL MILL MACHINERY* | **704,255** | **388,885** |
| *CIVIL WORKS:* | | |
| *Value of Existing Infrastructure* | 30,0000 | 100,000 |
| *Mill Foundation* | 15,195 | 9,915 |
| *Drying Yard* | 9,900 | 9,900 |
| *Site Clearing/Leveling* | 1,650 | 1,650 |
| *Laboratory/Office Renovation* | 11,000 | 11,000 |
| *Drainage* | 5,500 | 5,500 |
| *Factory Fencing* | 11,000 | 11,000 |
| *Oxidation Ponds* | 26,400 | 26,400 |
| *Workers Houses* | 17,600 | 17,600 |
| *Staff Houses* | 9,900 | 9,900 |
| *Factory Buildings* | 80,000 | 25,000 |
| *Leaf Yard* | 3,300 | 3,300 |
| *Roads & Bridges* | 22,000 | 22,000 |
| *SUB-TOTAL CIVIL WORKS* | **513,445** | **253,165** |
| GRAND TOTAL | 2,572,225 | 1,641,330 |

The above table shows the investment costs for both scenarios in detail but accumulated over the project life cycle. The figures have been entered into COMFAR aggregated. Furthermore, the differences with COMFAR results are due to the inflation factor applied during the calculation.

### *6.8 Civil Works*

Civil works for the three-hammer mill system and auxiliary equipment comprise of the following:

(i) Value of existing infrastructure put at the disposal of the project
(ii) Foundation structures including slabs
(iii) Support structure for conveyors, hammer mills including columns, rafts and walkways
(iv) Mucilage tanks for the storage of residual parenchyma and ponds for waste disposal
(v) Leaf yard and drying yard for the optimization period

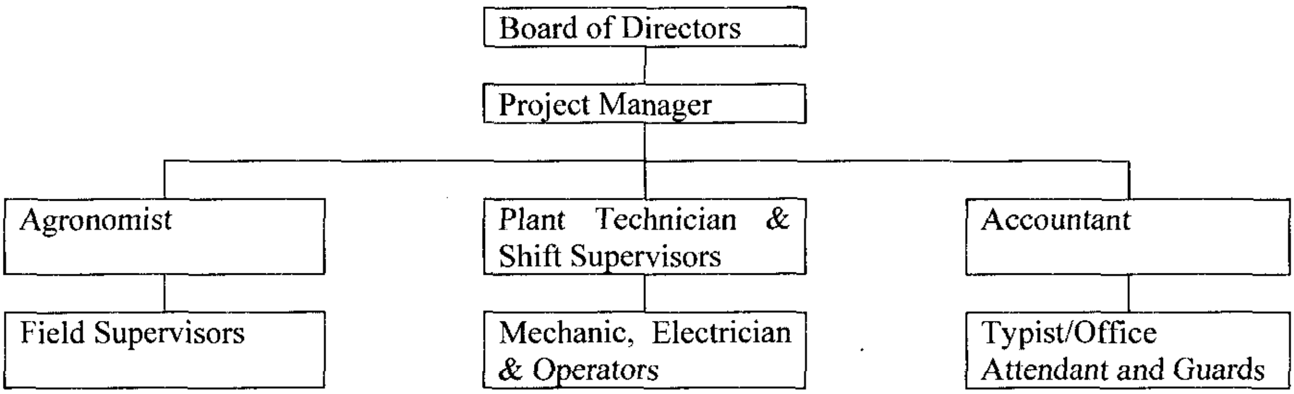
The cost of civil works is shown in table 13 above.

## 7.0 ORGANIZATION AND MANAGEMENT

### *7.1 Organization in General*

The overall organization structure of the project is shown in figure 6 below:

**Figure 6: Organization Structure for the Project**




#### 7.1.1 General management

The project will operate under a new subsidiary company of Katani Limited which shall be established under the company law - cap. 212. It will have a Board of Directors selected by Katani Limited and collaborating partners. The Board of Directors will be the highest decision making organ for all policy issues, general guidance and overall supervision of the company.

The overall responsibility for the project will be vested with the Project Manager who will be appointed by the Board of Directors. He will ensure that the strategic objectives and policies of the company are implemented. His duties will include planning, coordination, personnel and finance management and preparation and submission of periodic project reports to the Board. He will be assisted by an agricultural officer who will be responsible for field activities, an accountant responsible for administration and accounting functions and technicians and supervisors at the fibre extraction facility.

#### 7.1.2 Production

Actual production of sisal fibre from the FEX plant will be planned and organized in such a way as to meet sales targets. The production department will be responsible for the technical and technological aspects under supervision of the project engineer. It is important for this section to coordinate with the marketing department at Katani in order to synchronize production of staple fibre and sales requirements. Quantities produced each year are shown in Table 9 above.

#### 7.1.3 Sales

The marketing function will be undertaken at the Headquarters of Katani Ltd. It would have been desirable to set up an independent sales section at the plant, but since production of staple fibre at Hale will be under Katani, it is deemed reasonable to utilize the highly qualified and experienced marketing personnel at the Headquarters.

#### 7.1.4 Administration

An accounting unit headed by a project accountant will provide financial and accounting information necessary for reporting and management of the project. Envisaged project operations and transactions are straightforward and therefore the unit will combine functions of book keeping, accounting and purchasing. These functions will be undertaken in compliance with standard Katani procedures and regulations.

### *7.2 Overhead Costs*

#### 7.2.1 Factory Costs

Projected factory overhead costs covering insurance cost and other items change with scale of operations.

#### 7.2.2 Administrative Costs

Administrative overhead costs of the project will consist of salaries and wages of office staff, office supplies, rents and taxes.

## 8.0 HUMAN RESOURCES

### *8.1 Human Resource Needs*

The growing of sisal, maintenance, harvesting and leaf transport to the FEX plant will be undertaken by smallholders/outgrowers and their families. The labour required by smallholders and outgrowers is not shown as part of the project nor the cost accounted for. The project will provide tractors, trailers and equipment to facilitate the farmers but they will pay for the services. The project will grow and maintain ENT nurseries and sale seedlings to farmers for planting their fields.

A maximum of 112 people will be employed by year 2015. Most workers will come from surrounding villages and present workers families except for managerial and professional staff. The project will recruit more youths and women for unskilled tasks to help economically disadvantaged groups in the Tanzanian society.

At the managerial and supervisory level the project requires an engineer as project manager, an agronomist, an accountant, a technician, an electrician, two shift supervisors and two field supervisors. Katani Limited has qualified and experienced staff to take up all managerial and supervisory functions. During the project trial phase, 10 people were trained on the operation of the hammer mill and two qualified as operators and two as technicians. These people are available for recruitment in the FEX plant. Other operators and technicians will be recruited and trained by the engineer and other technicians. Personnel requirements for the project and their Curriculum Vitae are as given hereunder:

Project Manager/Engineer (1)

- University degree in mechanical, chemical processing or agricultural engineering
- Working experience in fibre extraction and pulping of at least 2 years

Technician (1)

- Full Technician Certificate - Grade I from a recognized national institute
- A minimum of 2 years of working experience

Electrician (3)

- Diploma in electrical engineering from recognized training institution
- A minimum of 2 years of working experience in a similar job

Mill Shift Supervisors (3)

- Trade Test Grade II or above
- Working experience on the hammer mill

Agronomist (1)

- Diploma in crop science from a recognized training institution
- Working experience in a sisal plantation of at least 3 years

Field Supervisors (2)

- Certificate in crop science from a recognized training institution or higher
- Working experience in a sisal plantation of at least 3 years

Accountant (1)

- Diploma in accountancy or higher from a recognized national institute
- A minimum of 2 years of working experience in a similar job

Typist (1)

- Certificate in secretarial duties or higher from a recognized national institute
- A minimum of 2 years of working experience in a similar job

Security Guards (3)

- Paramilitary course on security and a certificate of participation.
- Working experience in a sisal plantation is desirable

## 8.2 Wages, Salaries and Allowances

Casual labour will be paid on the basis of a specific rate per daily task (man-day) at the cost around US$ 2 per man-day. Wage payment will normally be done after completion of the assigned task. Managerial/supervisory cadres and support staff will be paid monthly salaries and allowances.

## 9.0 IMPLEMENTATION SCHEDULE

The estimated project duration is 11 years. The construction period of the FEX plant will last for two and a half years including one year for optimization. During this period 840 hectares of field sisal will be planted. A total of 34 hectares of nursery will be established in the first year, 12 hectares in the second year and 10 hectares each year thereafter. After the construction period production will commence and last 8 years. Main activities during the production period will be harvesting sisal, staple fibre production in the FEX plant and sale of the staple fibre.

**Table 14: Implementation Schedule During the Construction Period**

| ACTIVITY | July – Dec. 2005 | January- June 2006 | July –Dec. 2006 | Jan-June 2007 | July- Dec. 2007 | Responsible | Output |
|---|---|---|---|---|---|---|---|
| Submit final feasibility study | | | | | | Katani | Feasibility study |
| Optimize FEX System by providing bigger chipper, 2nd hammer mill, collector and discharge conveyors | | | | | | Katani | Optimized FEX |
| Project approval by CFC | | | | | | CFC | Approval |
| Sign loan agreement | | | | | | CFC/Katani | Agreement |
| Open project account | | | | | | Katani | Account |
| Disburse funds | | | | | | CFC/Katani | Funds |
| Recruit key personnel | | | | | | Katani | Personnel |
| Prepare land and plant nursery | | | | | | Katani | Nursery |
| Maintain nursery/apply fertilizer | | | | | | Katani | Healthy nursery |
| Prepare land and plant field sisal | | | | | | Katani | Field sisal |
| Maintain field sisal | | | | | | Katani | Healthy field sisal |
| Tender and award contracts for civil works | | | | | | Katani | Civil works contract |
| Construct civil works | | | | | | Contractor | Structures |
| Tender and award contracts for equipment | | | | | | Contractor | Supply contract |
| Deliver/install equipment | | | | | | Contractor | Equipment |
| Trial runs and commissioning | | | | | | Contractor | FEX Plant |

## 10.0 INVESTMENT AND FINANCIAL RESULTS

This chapter covers the financial evaluation of the project on the basis of the analysis and assumptions stated in the previous chapters. The analysis focuses mainly on the financial viability, but discusses also impacts of the project from the national economic viewpoint.

UNIDO's Computer Model for Feasibility Analysis and Reporting (COMFAR *III Expert*) was used for the financial evaluation and the following detailed financial statements and charts are provided in Annex 4 (2-Hammer Mill Fibre Extraction Plant) and Annex 5 (3-Hammer Mill Extraction Plant):

- Summary Sheet
- Total Fixed Investment Costs
- Total Pre-Production Expenditures
- Total Net Working Capital Requirements
- Total Investment Costs
- Total Annual Costs of Products
- Total Production and Sales Programme
- Total Sales (chart)
- Total Financial Flow
- Total Cash Flow for Financial Planning
- Discounted Cash Flow – Total Capital invested
- *Sensitivity of IRR (chart)*
- Cumulative Net Cash Flow – Normal Payback (chart)
- Cumulative Net Cash Flow – Dynamic Payback (chart)
- Discounted Cash Flow – Total Equity Capital invested
- Net Income Statement
- Total Break-Even Analysis
- Break-Even Ratio
- Projected Balance Sheet

The *outline of this chapter is as follows:*

- Assumptions used in the analysis
- The chief financial evaluation of the project is examined, i.e.,
  - Investment costs
  - Project financing
  - Production costs
- The financial viability is assessed based on the following analysis:
  - Cash Flow statements
  - IRR (Internal Rate of Return), NPV (Net Present Value), Pay-back Periods
  - Net Income Statement
  - Break-Even Analysis
  - Balance Sheet
- Sensitivity Analysis of IRR is made to ascertain how the profitability changes with respect to possible changes in sales, production costs and fixed investment costs.
- Conclusion

## *10.1 Assumptions*

### 10.1.1 Construction Period and Project Life

The construction phase of the plant will last for two years and six months including one year of optimization. The production phase is assumed to be 8 years, i.e.: the total project life of the project is 10 years and 6 months.

### 10.1.2 Currency

All calculations in the financial evaluation are expressed in US Dollar (US$). The following exchange rate applicable at the time of the preparation of the study is used:

1 US$ = 1,200 Tanzania Shilling

Furthermore, the analysis of both alternatives is based on a relative inflation rate between the US$ and the Tanzanian Shilling of 5.4% p.a. in 2006, 4.8% p.a. in 2007 and 4% p.a. as of 2008.

### 10.1.3 Corporate Tax

The project enjoys corporate tax holidays for five (5) years. From the sixth year onward, a corporate tax rate of 30% of taxable profits is applied. Losses are carried forward for eight (8) years.

### 10.1.4 Depreciation

For the calculation of depreciation the straight-line method is applied for all categories. The following depreciation rates and scrap (salvage) value rates are used:

| Category | Depreciation rate | Scrap value |
|---|---|---|
| Land preparation, Planting costs, Field maintenance, Soil analysis | 100% | 0% |
| Site preparation and development | 10% | 10% |
| Civil works, structures and buildings | 10% | 10% |
| Plant machinery and equipment | | |
| Mill machinery and equipment | 10% | 10% |
| Farm tractors, Vehicles and Equipment, Laboratory and Office Equipment | 20% | 10% |
| Environmental protection | 10% | 10% |
| Incorporated fixed assets – Project implementation | 33.3% | - |
| Pre-production expenditures | 20% | - |
| Contingencies | | |
| Mill machinery and equipment, Environmental protection, civil structures/site preparation | 10% | 10% |
| Farm tractors, Vehicles and Equipment, Laboratory and Office Equipment | 20% | 10% |

#### 10.1.5 Dividends

The project plans to retain 75% and to distribute 25% of the profit generated as of the first year of production.

## *10.2 Chief Financial Statements*

### 10.2.1 Total Investment Costs

Total investment costs for the 3-hammer mill FEX are estimated at US$ 3,322,110 (including capitalized interest of US$ 72,810 and working capital of US$ 360,480 as well as pre-production expenditures of US$ 53,960) while total investment costs for the 2-hammer mill FEX are US$ 2,079,840 (including capitalized interest of US$ 46,170, working capital of US$ 183,260 and pre-production expenditures of US$ 53,960). Table 13 above provides the breakdown.

### 10.2.2 Fixed Investment Costs

In the 3-hammer mill FEX fixed investment costs without the capitalized interest, working capital and pre-production costs are projected at US$ 2,834,850 (US$ 1,953,700 during the construction and US$ 881,150 during production) while in the 2-hammer mill FEX fixed investment costs without capitalized interest, working capital and pre-production costs are US$ 1,795,940 (US$ 1,197,460 during construction and US$ 598,480 during production).

### 10.2.3 Working Capital

Working capital requirements for the 3-hammer mill FEX are projected at US$ 360,480 while in the 2-hammer mill FEX they are US$ 183,260. The assumptions regarding working capital are summarized on Table 14 below.

**Table 14: Working Capital Assumptions**

| Item | Days Coverage |
|---|---|
| **Inventory** | |
| Cutting and leaf transport labour and non-labour items | 1 |
| Offloading, chipping, feeding labour and non-labour items | 1 |
| Hammer milling, drying and baling | 1 |
| Water, Energy | 0 |
| Factory supplies | 30 |
| Work in progress | 1 |
| Finished products | 14 |
| **Accounts Receivable** | |
| Accounts receivable local | 30 |
| Accounts receivable export | 45 |
| **Cash in hand** | **1** |
| **Accounts Payable:** | |
| Cutting and leaf transport non-labour | 30 |
| Offloading/chipping/feeding non-labour | 30 |
| Hammer milling/chipping factory supplies | 1 |
| Drying/baling factory supplies | 1 |
| Energy and water | 30 |
| Estate repair & maintenance non-labour | 30 |
| Mill repair & maintenance non-labour | 30 |
| Others non-labour | 30 |
| Administrative materials and services | 30 |
| Direct marketing costs | 30 |

### 10.2.4 Pre-production expenditure

Costs incurred by project before production start-up amount to US$ 53,960 (net of capitalized interest) in both scenarios. These will cover mainly the market studies, which have to be undertaken before production starts. Project implementation costs of US$ 74,610 applying to both scenarios are included in the fixed investment costs

### 10.2.5 Project Financing

#### 10.2.5.1 Capital structure and financing

Project financing in both scenarios is from two sources. In the 3-hammer mill FEX scenario Katani Limited the investors would be required to provide equity capital to the tune of US$ 613,737 consisting of US$ 400,000 in kind and US$ 213,737 in cash while in the 2-hammer mill FEX scenario total equity required would be US$ 301,525 comprising of US$ 150,000 in kind and US$ 151,525 in cash.

In the 3-hammer mill FEX US$ 976,750 (excluding capitalized interest) will be required as a soft loan from CFC while in the 2-hammer mill FEX the loan would amount to US$ 595,930 (excluding capitalized interest).

A grant of US$ 401,195 applies to both scenarios as the grant covers the cost of the investment already made in optimizing the FEX plant.

In the 3-hammer mill scenario fixed investment costs amounting to US$ 881,150 during the production period covering replacement and nursery planting will be financed from retained earnings while in the 2-hammer mill scenario these will be US$ 598,480.

Equity capital and the loan will be disbursed during the two and a half years of the construction period from year 2005 to 2007.

#### 10.2.5.2 Cost of finance

A grace period of 2 years after disbursement is recommended for the CFC loan. The interest rate used is 4% per annum plus 2% per annum for CFC fees for the outstanding balance. Unpaid interest during the construction period from 2005 to 2007 amounting to US$ 72,810 in the 3-hammer mill scenario and US$ 46,170 in the 2-hammer mill scenario will be capitalized. The capitalized interest together with the principal will be repaid in 5 equal annual repayments from 2010 to 2014.

### 10.2.6 Production Costs

Total production costs (factory costs, operating costs, costs of products and unit costs) are shown in COMFAR schedules and summarized in the tables below in thousands of US dollars.

**Table 15: Cost Comparisons between the Two Scenarios**

| | 3-HAMMER MILL FEX SCENARIO | | | | 2-HAMMER MILL FEX SCENARIO | | | |
|---|---|---|---|---|---|---|---|---|
| YEAR | Factory Costs | Operating Costs | Cost of Products | Unit Cost | Factory Costs | Operating Costs | Cost of Products | Unit Cost |
| 2008 | 698.04 | 818.83 | 1,212.29 | 0.71 | 338.89 | 426.62 | 679.59 | 0.80 |
| 2009 | 973.90 | 1,134.91 | 1,512.94 | 0.66 | 471.61 | 582.96 | 831.27 | 0.73 |
| 2010 | 1,342.37 | 1,550.18 | 1,961.83 | 0.64 | 648.79 | 786.38 | 1,046.79 | 0.68 |
| 2011 | 1,756.55 | 2,016.91 | 2,434.26 | 0.62 | 848.10 | 1,015.89 | 1,268.63 | 0.65 |
| 2012 | 1,931.79 | 2,221.04 | 2,617.23 | 0.64 | 933.03 | 1,119.42 | 1,347.17 | 0.65 |
| 2013 | 2,121.91 | 2,442.43 | 2,854.99 | 0.66 | 1,025.20 | 1,231.90 | 1,467.74 | 0.68 |
| 2014 | 2,252.48 | 2,603.02 | 3,018.02 | 0.67 | 1,088.14 | 1,315.30 | 1,557.94 | 0.69 |
| 2015 | 2,451.41 | 2,842.59 | 3,255.02 | 0.71 | 1,187.15 | 1,442.90 | 1,686.94 | 0.74 |

The 3-hammer mill FEX scenario has higher factory costs, operating costs and costs of products but lower unit costs than the 2-hammer mill FEX scenario.

### *10.3 Financial Evaluation*

Financial analysis and evaluation was undertaken using the COMFAR *III Expert* model of UNIDO. The project life is taken as 10 years and 6 months of which two and a half years are for construction and 8 years for production. The discount rate used in both scenarios was 12%.

#### 10.3.1 Cash Flow

As the Cash Flow for Financial Planning tables show (see Annexes 4 and 5), the project produces positive annual cash balances (accumulated annual cash flows) throughout the project life.
The cumulative cash balances at the end of the project amount to US$ 3,589,049 (3-Hammer Mill Option) and US$ 1,630,892 (2-Hammer Mill Option). Due to the significant generation of cash surplus, it could be considered to increase dividend payments and/or to reduce the repayment period for the loan.

#### 10.3.2 Internal Rate of Return (IRR) and Net present Value (NPV)

The Internal Rate of Return is one of the most important measures of overall project's worth. It can be interpreted as the maximum interest rate that a project can carry and still 'break even' in present values terms. As a rule of the thumb, if the IRR is greater than the discount rate then the investment is worthwhile.

The 3-hammer mill FEX yields an IRR of 19.13% on total capital invested while the 2-hammer mill FEX yield an IRR of 13.59%. The IRR to total equity invested in the 3-hammer mill FEX is 34.92% while the IRR to total equity invested in the 2-hammer mill FEX is 35.10%. The IRR to total equity invested is higher in the 2-hammer mill FEX due to the low equity investment. Based on the above results both scenarios are viable but the 3-hammer mill FEX is the most viable and is thus recommended for implementation.

#### 10.3.3 Payback period

The length of time required to recover the initial investment outlay through profits is outlined for both scenarios in table 16 below.

**Table 16: Payback Period**

| | 3-HAMMER MILL FEX | | 2-HAMMER MILL FEX | |
|---|---|---|---|---|
| | **Years** | **Year** | **Years** | **Year** |
| **Total Capital Invested** | | | | |
| Normal Payback at 0% | 7.27 | 2012 | 8.51 | 2013 |
| Dynamic Payback at 12% | 9.43 | 2014 | 11.48 | 2016 |
| **Total Equity Invested** | | | | |
| Normal Payback at 0% | 5.58 | 2010 | 5.61 | 2010 |
| Dynamic Payback at 20% | 7.57 | 2012 | 8.45 | 2013 |

The payback period is long reflecting low cash flow and low capacity utilization of the FEX plant. Sisal yield go through a normal curve scenario increasing up to the 6th cut and thereafter fall.

### 10.3.4 Net Income Statement

For the 3-Hammer Mill option the variable costs remain throughout the production period constant at approximately 40% of sales revenues. The majority of variable costs are material costs. Of the total fixed costs the depreciation charges, material and personnel costs account for the majority.

The project starts to make profits as of the second year of operations. The Net profit margin steadily increases from 8.68% (second year of operation) to 22.56% (fifth year of operation). As of the sixth year of operation (start of tax payment) the Net profit margin drops to approximately 16%.

For the 2-Hammer Mill option the variable costs remain throughout the production period constant at approximately 42% of sales revenues. The majority of variable costs are material costs. Of the total fixed costs the depreciation charges, material and personnel costs account for the majority.

The project starts to make profits as of the third ear of operations. The Net profit margin steadily increases from 9.98% (third year of operation) to 20.28% (fifth year of operation). As of the sixth year of operation (start of tax payment) the Net profit margin drops to approximately 14%.

### 10.3.5 Break-Even Analysis

For the 3-Hammer Mill option the project does not break even in the first year of operation. As of the second year of operations the break-even ratio drops from 78.51% to 41.18% at the end of the project life.

The calculations for the 2-Hammer Mill option indicate that project starts to break-even as of the third year of operations (76.59%). The break-even ratio improves towards the end of the project life to 51.37%.

### 10.3.6 Sensitivity analysis of IRR on Investment

The most sensitive variables in both scenarios were found to be sales revenues while changes on operating costs and fixed costs did not have a significant impact on the profitability of the project. Project management will have to monitor closely the movement of such variables and take remedial measures if adverse movements on these variables are observed.

### 10.4 Economic Evaluation

In the preceding section, the financial evaluation of the project was undertaken basically to assess the financial viability of the project using known criteria from the viewpoint of project sponsors. Such analysis was based on market prices i.e. those directly obtainable in the market to calculate different measures of project worth. Owing to some market imperfections, national economic evaluation is normally done to assess the viability of the project as related to the whole national economy. This analysis uses accounting prices sometimes known as shadow prices. However, due to the small-scale nature of the project, no substantial impact on the national economy is envisaged and therefore a fully-fledged economic analysis was deemed irrelevant.

### 10.5 Conclusion

Judging from the results of the above analysis, both project scenarios can be considered financially viable. The project's IRR on total investment and on total equity are 19.13% and 34.82% for the 3-Hammer Mill option, respectively 13.59% and 35.1% for the 2-Hammer Mill option. The Net Present Values of the two project alternatives are US$ 780,136.01 (3-Hammer Mill option) and US$ 101,896,34 (2-Hammer Mill option).

The project will purchase the required raw materials and other factory supplies locally but plans to export 50% of the finished products thus contributing positively to the national economy. Both alternatives start to generate profits relatively early after beginning of operations. The ratios calculated in the Net Income Statement as well as in the Projected Balance Sheet indicate that both alternatives are financially stable.

The project's IRR is in both scenarios sensitive towards the projects sales revenues. A drop of expected sales revenues by 8% (3-Hammer Mill scenario) respectively 3% only (2-Hammer Mill scenario) would cause the IRR to drop below the applied discounting rate of 12%. Therefore special attention should be put on the assumptions made concerning sales forecast.

Summarizing the above results and conclusions, the 3-Hammer Mill scenario is the most viable and is therefore recommended for implementation.

**Annex 1: Technical Specifications of FEX Plant Components**

**Three Hammer Mill FEX Plant**

2 Sisal Chippers with Sisal Leaf Conveyor

| | | |
|---|---|---|
| (i) | Type: | Rotary fitted with three heavy duty blades |
| (ii) | Discharge: | Blower mechanism |
| (iii) | Capacity: | 12 tons per hour |
| (iv) | Drive system: | Geared motor 7.5 kW drive leaf-feeding mechanism |
| (v) | Installation: | To be fixed at the chip yard |
| (vi) | Feeding: | Inclined plate with conveyor system for sisal leaves |

Chips Supply Conveyor

Transport of sisal chips and processed fibre in the mill will be done using flat belt conveyors. These are designed with the following main features: robust and rigid main support frame from SAE 1020 C-channels angles and plates; flat belt installation with wide supports to protect sisal chips from falling off; evenly spaced steel rollers located between the driven and driving rollers for supporting the conveyor belt.

| | | |
|---|---|---|
| (i) | Type: | Flat conveyor belt with site protection |
| (ii) | Delivery capacity: | 24 tons per hour |
| (iii) | Drum center distance: | 12,000 mm |
| (iv) | Overall width: | 1,127 mm belt conveyor or 1,800 mm including walkways |
| (v) | Inclination: | $12^0$ |
| (vi) | Drive: | Geared motor, 7.5 kW |
| (vii) | Conveyor belt speed: | 42 metres per minute |
| (viii) | Belt type: | Breda B20CF, 762 wide |
| (ix) | Coupling: | Flexible coupling torque capacity of 2170 Nm @ 33 rpm |

Chips Feeding Conveyor

Main features of the feeding conveyor are the same as the chip supply conveyor.

| | | |
|---|---|---|
| (i) | Type: | Flat conveyor belt with protection |
| (ii) | Delivery capacity: | 24 tons per hour |
| (iii) | Drum center distance: | 8,000 mm |
| (iv) | Overall width: | 1,127 mm conveyor belt or 1,800 mm including walkways |
| (v) | Inclination: | $18^0$ |
| (vi) | Drive: | Geared motor 7.5 kW @ 1500 rpm, ratio 44.88:7 |
| (vii) | Conveyor belt speed: | 4 metres per minute |
| (viii) | Belt type: | Breda B20CF, 762 mm wide |
| (ix) | Coupling: | Flexible coupling torque capacity of 2170 NM @ 33 rpm |

Helicoidal Conveyor $\phi$ 420

| | | |
|---|---|---|
| (i) | Type: | Screw conveyor |
| (ii) | Overall length: | 5300 mm |
| (iii) | Overall height: | 720 mm |
| (iv) | Weight: | 1,240 kg |
| (v) | Drive: | Geared motor, 7.5 kW 1,500 rpm and ratio 44.88:7 |
| (vi) | Coupling: | Flexible coupling torque capacity of 2,170 Nm @ 33 rpm |
| (vii) | Delivery capacity: | 25 tons of sisal chips per hour |

Rotating Dosing Feeder

| | | |
|---|---|---|
| (i) | Type: | Rotary impeller |
| (ii) | Overall length: | 760 mm |
| (iii) | Overall height: | 820 mm |
| (iv) | Weight: | 320 kg |
| (v) | Drive: | Geared motor, 1.5 kW 1,500 rpm |
| (vi) | Charge regulation: | Frequency inverter, 0-50 Hz |
| (vii) | Coupling: | Flexible coupling torque capacity of 2,170 Nm @ 33 rpm |
| (viii) | Delivery capacity: | 12 tons of sisal chips per hour |

Helicoidal Conveyor $\phi$ 280

| | | |
|---|---|---|
| (i) | Type: | Screw conveyor |
| (ii) | Overall length: | 2700 mm |
| (iii) | Overall height: | 540 mm |
| (iv) | Weight: | 380 kg |
| (v) | Drive: | Geared motor, 2.2 kW 1,500 rpm and ratio 44.88:7 |
| (vi) | Coupling: | Flexible coupling torque capacity of 2,170 Nm @ 33 rpm |
| (vii) | Delivery capacity: | 12 tons of sisal chips per hour |

VERTICAL MILL

| | | |
|---|---|---|
| (i) | Type: | Vertical in line, rotary swinging hammers |
| (ii) | Number of hammers: | 68 |
| (iii) | Overall height: | 1,750 mm |
| (iv) | Overall width: | 1,340 mm |
| (v) | Weight: | 2,200 kg |
| (vi) | Milling capacity: | 12 tons of sisal chips per hour |
| (vii) | Power requirements: | 3-phase electric motor, 100 HP @ 950 rpm |
| (viii) | Belt drive: | 5V 1400, V-belts |

Discharge Conveyors

This conveyor has the same main features as the other flat belt conveyors.

| | | |
|---|---|---|
| (i) | Type: | Perforated flat conveyor belt with protection |
| (ii) | Delivery capacity: | 2 tons of wet fibre per hour |
| (iii) | Drum center distance: | 8,000 mm |

| | | |
|---|---|---|
| (iv) | Overall width: | 1,127 mm conveyor belt or 1800 mm including walkways |
| (v) | *Inclination:* | $15^0$ |
| (vi) | Drive: | Geared motor, 5 kW @ 1,500 rpm |
| (vii) | Conveyor belt speed: | 45 metres per minute |
| (viii) | Belt type: | Breda B20CF, 762 wide |
| (ix) | Coupling: | Flexible coupling torque capacity of 2,170 Nm @ 33 rpm |

DRYING AND BALING

Squeezer

A wet fibre squeezer similar to one used in the flume-tow recovery plant will be used for removal of water prior to drying.

| | | |
|---|---|---|
| (i) | Type: | Vertical in line, rotary swinging hammers |
| (ii) | Overall width: | 1,300 mm |
| (iii) | Overall height: | 2,500 mm |
| (iv) | Capacity: | 2 tons of wet fibre per hour |
| (v) | Drive: | Geared motor, 7.5 kW |

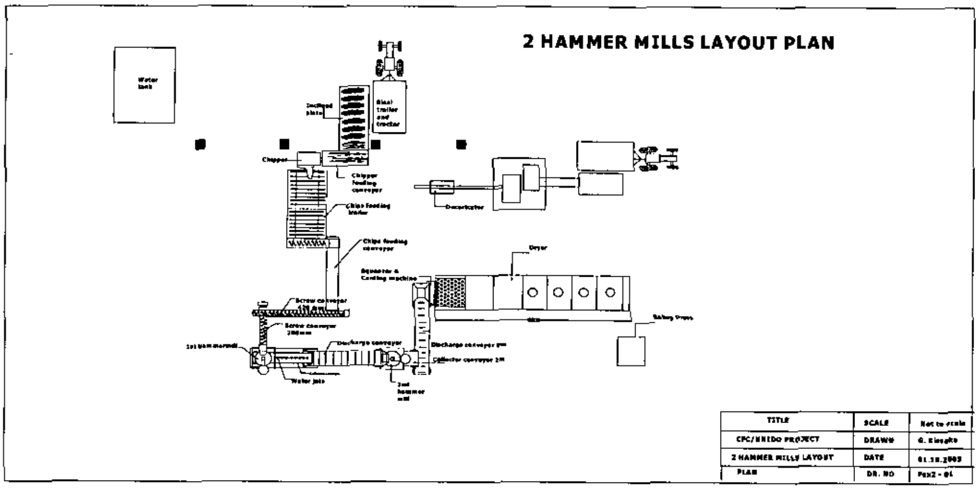
Dryer

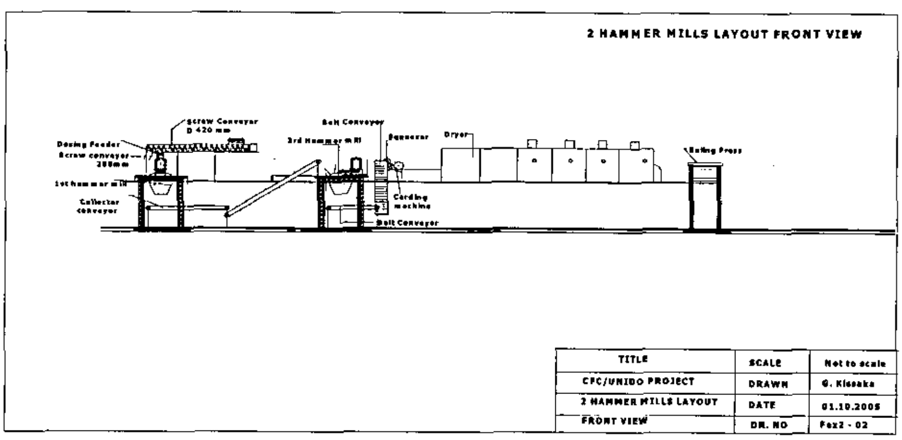
| | | |
|---|---|---|
| (i) | Type: | Gas dryer |
| (ii) | Capacity: | 1.5 tons of squeezed fibre per hour |

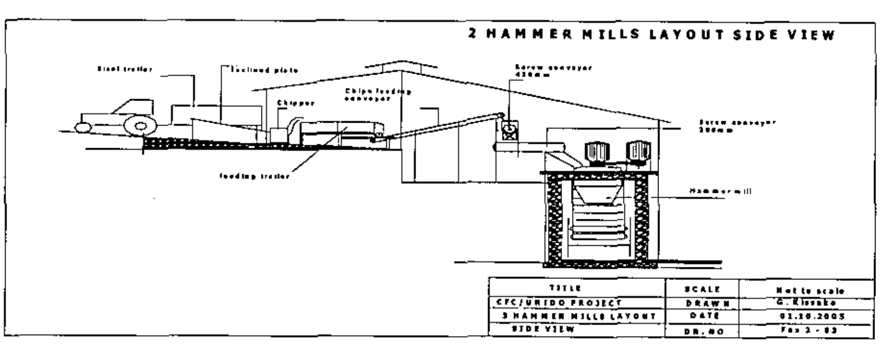
Baling Machine

| | | |
|---|---|---|
| (i) | Type: | Hydraulic press |
| (ii) | Capacity: | 1 ton of dry fibre per hour |
| (iii) | Box size: | Length 1,500 mm, Width 600 mm, Depth 2,500 mm |
| (iv) | Operating pressure: | 100 bar |

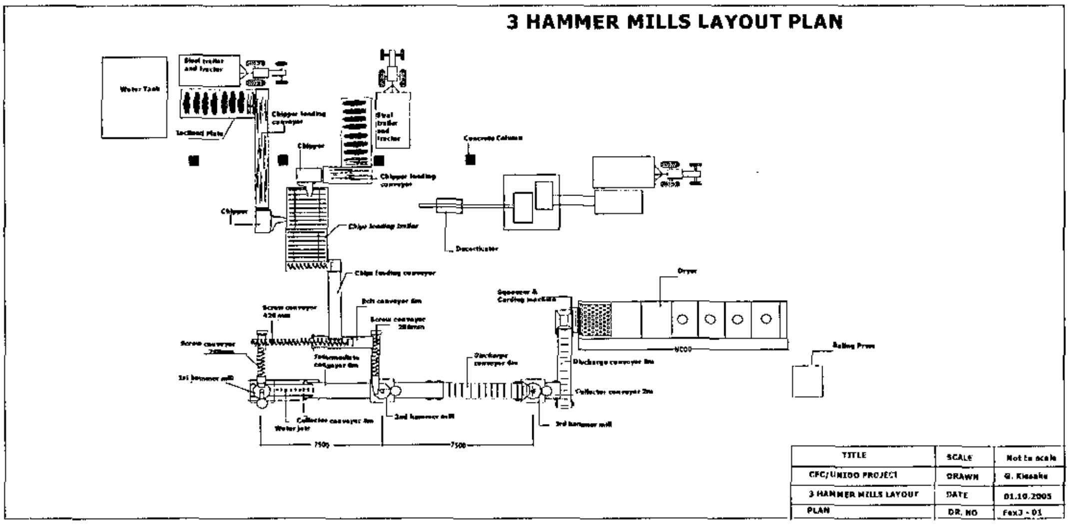
# Annex 2: Two-Hammer Mill FEX Plant Layout

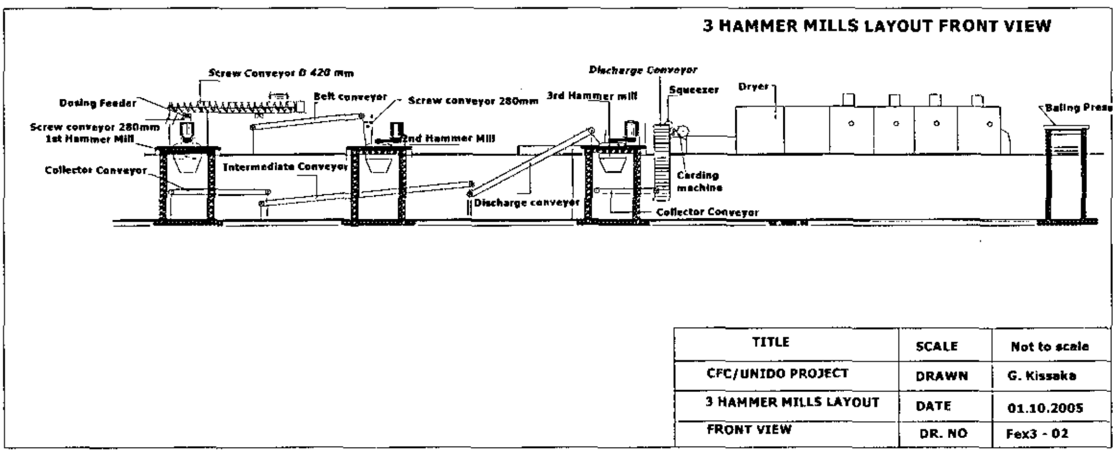


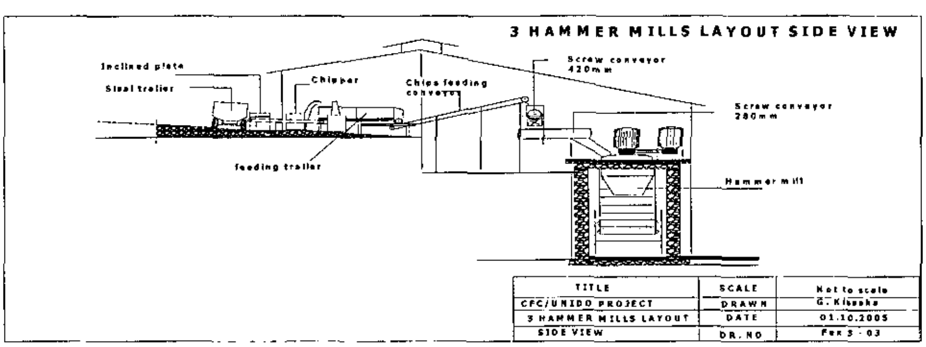



# Annex 3: 3-HAMMER MILL LAYOUT



## SUMMARY SHEET

| | |
|---|---|
| Project title: | Sisal Fibre Extraction Project |
| Project description: | The Project will involve growing of sisal by smallholders and outgrowers on 1,890 hectares who will in turn sell sisal leaves to the project for processing. Two hammer mills will process sisal leaves and boles to produce pulpable fibre for local and export market. Domestic inflation rate is expected to average 5.4% in 2006 due to food shortages caused by drought but fall to the previous 4.8% in 2007 and thereafter remain at around 4.0% . |
| Date and time: | 30 NOVEMBER 2005 |
| Project classification: | New project |
| Construction phase: | 7/2005 - 12/2007 |
| Length: | 2 years, 6 months |
| Production phase: | 1/2008 - 12/2015 |
| Length: | 8 years |
| Accounting currency: | US Dollar ('000) (US$) |
| Units: | Absolute |
| Local currency: | Tanzania Shillings ('000) (TSH) |
| Exchange rate: | 1.0000 US$ = 1,200.0000 TSH |

INVESTMENT COSTS

| | Total construction | Total production | Total investment |
|---|---|---|---|
| Total fixed investment costs | 1,197.46 | 598.48 | 1,795.94 |
| Total pre-production expenditures | 100.14 | 0.00 | 100.14 |
| *Pre-production expenditures (net of interest)* | *53.96* | *0.00* | *53.96* |
| *Interest* | *46.17* | *0.00* | *46.17* |
| Increase in net working capital | 0.00 | 183.26 | 183.26 |
| TOTAL INVESTMENT COSTS | 1,297.60 | 781.74 | 2,079.34 |

SOURCES OF FINANCE

| | Total construction | Total production | Total inflow |
|---|---|---|---|
| Total equity capital | 702.72 | 0.00 | 702.72 |
| *Foreign* | *401.19* | *0.00* | *401.19* |
| *Local* | *301.52* | *0.00* | *301.52* |
| Total long-term loans | 675.93 | 0.00 | 675.93 |
| *Foreign* | *675.93* | *0.00* | *675.93* |
| *Local* | *0.00* | *0.00* | *0.00* |
| Total short-term loans | 0.00 | 0.00 | 0.00 |
| *Foreign* | *0.00* | *0.00* | *0.00* |
| *Local* | *0.00* | *0.00* | *0.00* |
| Accounts payable | 0.00 | 43.74 | 43.74 |
| TOTAL SOURCES OF FINANCE | 1,378.65 | 43.74 | 1,422.39 |

INCOME AND COSTS, OPERATIONS

| | First year | Reference year | Last year |
|---|---|---|---|

## SUMMARY SHEET

| | 2008 | 2008 | 2015 |
|---|---|---|---|
| SALES REVENUE | 575.57 | 575.57 | 2,115.73 |
| Factory costs | 338.89 | 338.89 | 1,187.15 |
| Administrative overhead costs | 87.72 | 87.72 | 255.75 |
| OPERATING COSTS | 426.62 | 426.62 | 1,442.90 |
| Depreciation | 206.40 | 206.40 | 176.15 |
| *Financial costs* | 28.77 | 28.77 | 0.00 |
| TOTAL PRODUCTION COSTS | 661.79 | 661.79 | 1,619.04 |
| Marketing costs | 17.80 | 17.80 | 67.89 |
| COSTS OF PRODUCTS | 679.59 | 679.59 | 1,686.94 |
| Interest on short-term deposits | 0.00 | 0.00 | 0.00 |
| GROSS PROFIT FROM OPERATIONS | -104.03 | -104.03 | 428.80 |
| Extraordinary income | 0.00 | 0.00 | 0.00 |
| Extraordinary loss | *0.00* | *0.00* | *0.00* |
| Depreciation allowances | 0.00 | 0.00 | 0.00 |
| GROSS PROFIT | -104.03 | -104.03 | 428.80 |
| Investment allowances | 0.00 | 0.00 | 0.00 |
| TAXABLE PROFIT | 0.00 | 0.00 | 428.80 |
| Income (corporate) tax | 0.00 | 0.00 | 128.64 |
| NET PROFIT | -104.03 | -104.03 | 300.16 |

RATIOS

| | | |
|---|---|---|
| Net Present Value of Total Capital Invested | at 12.00% | 101.90 |
| Internal rate of return on investment (IRR) | 13.59% | |
| *Modified IRR on investment* | 13.59% | |
| Net Present Value of Total Equity Capital Invested | at 20.00% | 223.46 |
| Internal rate of return on equity (IRRE) | 35.10% | |
| Modified IRRE on equity | 35.10% | |
| Net present values discounted to | 7/2005 | |

**FIXED INVESTMENT COSTS - TOTAL**
US Dollar ('000)

| | Total construction | Total production | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land purchase | 78.84 | 56.37 | 0.00 | 71.78 | 7.06 | 6.12 | 6.36 | 6.62 | 6.88 | 7.16 | 7.44 | 7.74 | 8.05 |
| *Land purchase* | *52.70* | *0.00* | *0.00* | *52.70* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Land preparation* | *13.50* | *29.11* | *0.00* | *9.85* | *3.65* | *3.16* | *3.29* | *3.42* | *3.55* | *3.70* | *3.84* | *4.00* | *4.16* |
| *Planting costs* | *4.42* | *9.53* | *0.00* | *3.23* | *1.19* | *1.03* | *1.08* | *1.12* | *1.16* | *1.21* | *1.26* | *1.31* | *1.36* |
| *Field maintenance* | *5.77* | *12.44* | *0.00* | *4.21* | *1.56* | *1.35* | *1.40* | *1.46* | *1.52* | *1.58* | *1.64* | *1.71* | *1.78* |
| *Soil analysis* | *2.45* | *5.29* | *0.00* | *1.79* | *0.66* | *0.57* | *0.60* | *0.62* | *0.65* | *0.67* | *0.70* | *0.73* | *0.76* |
| Site preparation and development | 29.20 | 0.00 | 0.00 | 1.58 | 27.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Civil works, structures and buildings | 197.05 | 0.00 | 129.64 | 17.71 | 49.71 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Plant machinery and equipment | 724.30 | 492.83 | 177.91 | 353.09 | 193.30 | 25.85 | 0.00 | 46.59 | 54.92 | 269.45 | 52.41 | 43.61 | 0.00 |
| *Mill Machinery & Equipment* | *381.31* | *0.00* | *95.19* | *183.40* | *102.73* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Farm Tractors, Vehicles & Equipment* | *240.48* | *377.46* | *75.00* | *165.48* | *0.00* | *25.85* | *0.00* | *46.59* | *49.75* | *159.25* | *52.41* | *43.61* | *0.00* |
| *Laboratory & Office Equipment* | *102.52* | *115.37* | *7.73* | *4.22* | *90.58* | *0.00* | *0.00* | *0.00* | *5.17* | *110.20* | *0.00* | *0.00* | *0.00* |
| Auxiliary and service plant equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Environmental protection | 26.51 | 0.00 | 0.00 | 0.00 | 26.51 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Site preparation* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Civil works* | *26.51* | *0.00* | *0.00* | *0.00* | *26.51* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Plant machinery and equipment* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Incorporated fixed assets (project overheads) | 74.61 | 0.00 | 74.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Technology* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Project implementation* | *74.61* | *0.00* | *74.61* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Miscellaneous project overhead costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Contingencies | 66.95 | 49.28 | 0.00 | 37.24 | 29.71 | 2.58 | 0.00 | 4.66 | 5.49 | 26.95 | 5.24 | 4.36 | 0.00 |
| *Mill Machinery & Equipment* | *28.61* | *0.00* | *0.00* | *18.34* | *10.27* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Farm Tractors, Vehicles & Implements* | *16.55* | *37.75* | *0.00* | *16.55* | *0.00* | *2.58* | *0.00* | *4.66* | *4.98* | *15.93* | *5.24* | *4.36* | *0.00* |
| *Laboratory & Office Equipment* | *9.48* | *11.54* | *0.00* | *0.42* | *9.06* | *0.00* | *0.00* | *0.00* | *0.52* | *11.02* | *0.00* | *0.00* | *0.00* |
| *Environmental Protection* | *2.65* | *0.00* | *0.00* | *0.00* | *2.65* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Civil Structures/Site Preparation* | *9.66* | *0.00* | *0.00* | *1.93* | *7.73* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| TOTAL FIXED INVESTMENT COSTS | 1,197.46 | 598.48 | 382.16 | 481.40 | 333.91 | 34.55 | 6.36 | 57.87 | 67.29 | 303.55 | 65.10 | 55.71 | 8.05 |
| Foreign share (%) | 65.05 | 90.58 | 46.55 | 80.68 | 63.68 | 82.29 | 0.00 | 88.57 | 89.77 | 97.64 | 88.57 | 86.11 | 0.00 |

**PRE-PRODUCTION EXPENDITURES - TOTAL**
US Dollar ('000)

| | Total construction | Total production | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pre-investment studies | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Preparatory investigations | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Company formation, fees etc. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Project management, organization | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Technology acquisition | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Detailed engineering, contracting | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pre-production supplies, marketing | 53.96 | 0.00 | 0.00 | 26.35 | 27.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other capital (issue) expenditures | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Contingencies | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pre-production expenditures (net of interest) | 53.96 | 0.00 | 0.00 | 26.35 | 27.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interest | 46.17 | 0.00 | 0.00 | 19.57 | 26.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL PRE-PRODUCTION EXPENDITURES | 100.14 | 0.00 | 0.00 | 45.92 | 54.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Foreign share (%) | 46.11 | 0.00 | 0.00 | 42.62 | 49.06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**NET WORKING CAPITAL REQUIREMENTS - TOTAL**

US Dollar ('000)

| | Coefficient of turnover | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total inventory | 0.00 | 0.00 | 0.00 | 0.00 | 20.04 | 27.59 | 37.45 | 48.56 | 53.50 | 58.84 | 62.82 | 68.62 |
| *Raw materials* | *0.00* | *0.00* | *0.00* | *0.00* | *0.64* | *0.93* | *1.31* | *1.73* | *1.90* | *2.09* | *2.19* | *2.36* |
| Leaf Purchase | 360.00 | 0.00 | 0.00 | 0.00 | 0.64 | 0.93 | 1.31 | 1.73 | 1.90 | 2.09 | 2.19 | 2.36 |
| *Factory supplies* | *0.00* | *0.00* | *0.00* | *0.00* | *1.86* | *2.68* | *3.76* | *4.97* | *5.47* | *6.00* | *6.45* | *6.85* |
| Hammer Milling | 12.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.29 | 0.41 | 0.55 | 0.60 | 0.66 | 0.71 | 0.75 |
| Drying | 12.00 | 0.00 | 0.00 | 0.00 | 1.66 | 2.39 | 3.35 | 4.42 | 4.87 | 5.34 | 5.75 | 6.09 |
| Baling/stacking | 360.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Utilities* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Water | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Energy* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Energy kWh | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Energy KVA/Fees | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Spare parts consumed* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Work in progress* | *360.00* | *0.00* | *0.00* | *0.00* | *0.94* | *1.31* | *1.80* | *2.36* | *2.59* | *2.85* | *3.02* | *3.30* |
| *Finished product* | *25.71* | *0.00* | *0.00* | *0.00* | *16.59* | *22.67* | *30.58* | *39.51* | *43.53* | *47.91* | *51.15* | *56.11* |
| Accounts receivable | 0.00 | 0.00 | 0.00 | 0.00 | 46.29 | 63.47 | 85.77 | 110.92 | 122.25 | 134.51 | 143.67 | 157.37 |
| Cash-in-hand | 360.00 | 0.00 | 0.00 | 0.00 | 0.32 | 0.40 | 0.50 | 0.61 | 0.69 | 0.77 | 0.85 | 1.00 |
| CURRENT ASSETS | 0.00 | 0.00 | 0.00 | 0.00 | 66.65 | 91.46 | 123.72 | 160.09 | 176.43 | 194.12 | 207.35 | 226.99 |
| Accounts payable | 0.00 | 0.00 | 0.00 | 0.00 | 14.63 | 19.28 | 25.10 | 31.56 | 34.61 | 37.83 | 40.68 | 43.74 |
| *Raw materials* | *0.00* | *0.00* | *0.00* | *0.00* | *0.65* | *0.93* | *1.31* | *1.73* | *1.90* | *2.09* | *2.19* | *2.36* |
| Leaf Purchase | 360.00 | 0.00 | 0.00 | 0.00 | 0.65 | 0.93 | 1.31 | 1.73 | 1.90 | 2.09 | 2.19 | 2.36 |
| *Factory supplies* | *0.00* | *0.00* | *0.00* | *0.00* | *2.02* | *2.74* | *3.84* | *5.05* | *5.49* | *6.03* | *6.47* | *6.86* |
| Hammer Milling | 12.00 | 0.00 | 0.00 | 0.00 | 0.22 | 0.30 | 0.42 | 0.56 | 0.60 | 0.66 | 0.71 | 0.75 |
| Drying | 12.00 | 0.00 | 0.00 | 0.00 | 1.80 | 2.44 | 3.42 | 4.50 | 4.89 | 5.36 | 5.76 | 6.10 |
| Baling/stacking | 360.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Utilities* | *0.00* | *0.00* | *0.00* | *0.00* | *0.02* | *0.02* | *0.02* | *0.02* | *0.02* | *0.02* | *0.02* | *0.02* |
| Water | 12.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| *Energy* | *0.00* | *0.00* | *0.00* | *0.00* | *2.68* | *3.37* | *4.28* | *5.29* | *5.75* | *6.22* | *6.64* | *7.02* |
| Energy kWh | 12.00 | 0.00 | 0.00 | 0.00 | 1.48 | 2.13 | 2.99 | 3.95 | 4.35 | 4.77 | 5.13 | 5.44 |
| Energy KVA/Fees | 12.00 | 0.00 | 0.00 | 0.00 | 1.20 | 1.24 | 1.29 | 1.35 | 1.40 | 1.46 | 1.51 | 1.57 |
| *Spare parts consumed* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Repair, maintenance, material* | *0.00* | *0.00* | *0.00* | *0.00* | *2.53* | *3.05* | *3.72* | *4.44* | *4.86* | *5.28* | *5.67* | *6.01* |
| Repair, maintenance estate | 0.00 | 0.00 | 0.00 | 0.00 | 1.41 | 1.60 | 1.84 | 2.09 | 2.29 | 2.50 | 2.69 | 2.86 |
| *Estate Maintenance Labour* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Estate Maintenance Non-labour* | *12.00* | *0.00* | *0.00* | *0.00* | *1.41* | *1.60* | *1.84* | *2.09* | *2.29* | *2.50* | *2.69* | *2.86* |
| Repair, maintenance mill | 0.00 | 0.00 | 0.00 | 0.00 | 0.71 | 1.01 | 1.42 | 1.86 | 2.05 | 2.25 | 2.42 | 2.57 |
| *Mill Maintenance Labour* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Mill Maintenance Non-labour* | *12.00* | *0.00* | *0.00* | *0.00* | *0.71* | *1.01* | *1.42* | *1.86* | *2.05* | *2.25* | *2.42* | *2.57* |
| Repair, maintenance Buildings/Roads | 12.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.43 | 0.46 | 0.49 | 0.51 | 0.54 | 0.56 | 0.59 |
| *Royalties* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Labour* | *0.00* | *0.00* | *0.00* | *0.00* | *0.01* | *0.02* | *0.02* | *0.03* | *0.04* | *0.04* | *0.05* | *0.07* |
| Hammer Milling | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Drying | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Baling/Stacking | 360.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.02 | 0.03 | 0.04 | 0.04 | 0.05 | 0.07 |
| *Labour overhead costs (taxes etc.)* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Factory overhead costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.14* | *0.12* | *0.10* | *0.08* | *0.09* | *0.07* | *0.04* | *0.02* |
| Salaries, wages | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**NET WORKING CAPITAL REQUIREMENTS - TOTAL**
US Dollar ('000)

| | Coefficient of turnover | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social costs etc. (on salaries) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Materials and services | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Rents, leasing costs* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Insurance | 12.00 | 0.00 | 0.00 | 0.00 | 0.14 | 0.12 | 0.10 | 0.08 | 0.09 | 0.07 | 0.04 | 0.01 |
| Cess | 360.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Administrative costs* | *0.00* | *0.00* | *0.00* | *0.00* | *5.11* | *6.84* | *8.72* | *10.83* | *11.95* | *13.13* | *14.26* | *15.72* |
| Salaries, wages | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Social costs etc. (on salaries) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Materials and services | 12.00 | 0.00 | 0.00 | 0.00 | 2.85 | 3.49 | 4.02 | 4.61 | 5.07 | 5.57 | 6.12 | 7.09 |
| Rents, leasing costs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Management costs | 12.00 | 0.00 | 0.00 | 0.00 | 2.26 | 3.34 | 4.70 | 6.21 | 6.88 | 7.55 | 8.13 | 8.63 |
| *Leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Direct marketing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *1.48* | *2.19* | *3.08* | *4.08* | *4.51* | *4.95* | *5.33* | *5.66* |
| Salaries, wages | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Rents, leasing costs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other direct costs | 12.00 | 0.00 | 0.00 | 0.00 | 1.48 | 2.19 | 3.08 | 4.08 | 4.51 | 4.95 | 5.33 | 5.66 |
| CURRENT LIABILITIES | 0.00 | 0.00 | 0.00 | 0.00 | 14.63 | 19.28 | 25.10 | 31.56 | 34.61 | 37.83 | 40.68 | 43.74 |
| TOTAL NET WORKING CAPITAL REQUIREMENTS | 0.00 | 0.00 | 0.00 | 0.00 | 52.02 | 72.18 | 98.62 | 128.54 | 141.82 | 156.29 | 166.67 | 183.26 |
| INCREASE IN NET WORKING CAPITAL | 0.00 | 0.00 | 0.00 | 0.00 | 52.02 | 20.16 | 26.44 | 29.91 | 13.28 | 14.47 | 10.38 | 16.59 |
| Foreign share (%) | 0.00 | 0.00 | 0.00 | 0.00 | 3.77 | 3.48 | 3.26 | 3.10 | 3.09 | 3.07 | 3.10 | 2.99 |

**INVESTMENT COSTS - TOTAL**

US Dollar ('000)

| | Total construction | Total production | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total fixed investment costs | 1,197.46 | 598.48 | 382.16 | 481.40 | 333.91 | 34.55 | 6.36 | 57.87 | 67.29 | 303.55 | 65.10 | 55.71 | 8.05 |
| Total pre-production expenditures | 100.14 | 0.00 | 0.00 | 45.92 | 54.21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Pre-production expenditures (net of interest)* | *53.96* | *0.00* | *0.00* | *26.35* | *27.61* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Interest* | *46.17* | *0.00* | *0.00* | *19.57* | *26.60* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Increase in net working capital | 0.00 | 183.26 | 0.00 | 0.00 | 0.00 | 52.02 | 20.16 | 26.44 | 29.91 | 13.28 | 14.47 | 10.38 | 16.59 |
| TOTAL INVESTMENT COSTS | 1,297.60 | 781.74 | 382.16 | 527.32 | 388.12 | 86.57 | 26.52 | 84.31 | 97.21 | 316.84 | 79.57 | 66.09 | 24.64 |
| Foreign share (%) | 63.59 | 70.05 | 46.55 | 77.37 | 61.64 | 35.11 | 2.07 | 61.62 | 62.94 | 93.68 | 72.98 | 73.13 | 1.31 |

**ANNUAL COSTS OF PRODUCTS - TOTAL**
US Dollar ('000)

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| Capacity utilization (%) | 37.19 | 50.07 | 67.54 | 85.60 | 90.04 | 94.98 | 98.20 | 100.07 |
| Raw materials | 231.64 | 333.49 | 469.98 | 623.76 | 685.40 | 751.31 | 790.01 | 849.50 |
| *Leaf Purchase* | *231.64* | *333.49* | *469.98* | *623.76* | *685.40* | *751.31* | *790.01* | *849.50* |
| Factory supplies | 22.35 | 32.16 | 45.15 | 59.60 | 65.63 | 72.01 | 77.46 | 82.16 |
| *Hammer Milling* | *2.46* | *3.53* | *4.96* | *6.55* | *7.21* | *7.91* | *8.51* | *9.03* |
| *Drying* | *19.89* | *28.62* | *40.19* | *53.05* | *58.41* | *64.09* | *68.94* | *73.13* |
| *Baling/stacking* | *0.00* | *0.00* | *0.01* | *0.01* | *0.01* | *0.01* | *0.01* | *0.01* |
| Utilities | 0.20 | 0.21 | 0.22 | 0.23 | 0.24 | 0.24 | 0.25 | 0.26 |
| *Water* | *0.20* | *0.21* | *0.22* | *0.23* | *0.24* | *0.24* | *0.25* | *0.26* |
| Energy | 32.11 | 40.49 | 51.41 | 63.52 | 68.94 | 74.69 | 79.72 | 84.18 |
| *Energy kWh* | *17.76* | *25.56* | *35.88* | *47.37* | *52.15* | *57.22* | *61.56* | *65.29* |
| *Energy KVA/Fees* | *14.36* | *14.93* | *15.53* | *16.15* | *16.79* | *17.47* | *18.16* | *18.89* |
| Spare parts consumed | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Repair, maintenance, material | 39.44 | 47.62 | 58.17 | 69.78 | 77.27 | 85.64 | 93.68 | 105.22 |
| *Repair, maintenance estate* | *20.99* | *24.02* | *27.80* | *31.72* | *35.20* | *38.97* | *42.65* | *48.29* |
| Estate Maintenance Labour | 4.02 | 4.76 | 5.67 | 6.68 | 7.69 | 9.00 | 10.41 | 13.93 |
| Estate Maintenance Non-labour | 16.97 | 19.26 | 22.12 | 25.05 | 27.51 | 29.97 | 32.24 | 34.36 |
| *Repair, maintenance mill* | *13.54* | *18.40* | *24.84* | *32.17* | *35.92* | *40.22* | *44.30* | *49.91* |
| Mill Maintenance Labour | 5.02 | 6.23 | 7.84 | 9.80 | 11.30 | 13.22 | 15.26 | 19.12 |
| Mill Maintenance Non-labour | 8.51 | 12.17 | 17.00 | 22.38 | 24.62 | 27.00 | 29.04 | 30.79 |
| *Repair, maintenance Buildings/Roads* | *4.91* | *5.20* | *5.53* | *5.88* | *6.16* | *6.45* | *6.73* | *7.02* |
| Royalties | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Labour | 11.53 | 16.24 | 22.68 | 30.27 | 34.45 | 40.48 | 46.50 | 65.63 |
| *Hammer Milling* | *6.20* | *8.49* | *11.61* | *15.28* | *17.33* | *20.31* | *23.29* | *32.84* |
| *Drying* | *0.98* | *1.48* | *2.17* | *2.99* | *3.42* | *4.04* | *4.65* | *6.58* |
| *Baling/Stacking* | *4.35* | *6.27* | *8.90* | *12.01* | *13.70* | *16.14* | *18.55* | *26.20* |
| Labour overhead costs (taxes etc.) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Factory overhead costs | 1.63 | 1.41 | 1.18 | 0.95 | 1.10 | 0.82 | 0.52 | 0.19 |
| *Salaries, wages* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Social costs etc. (on salaries)* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Materials and services* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Rents, leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Insurance* | *1.62* | *1.41* | *1.17* | *0.94* | *1.09* | *0.81* | *0.51* | *0.18* |
| *Cess* | *0.00* | *0.00* | *0.01* | *0.01* | *0.01* | *0.01* | *0.01* | *0.01* |
| FACTORY COSTS | 338.89 | 471.61 | 648.79 | 848.10 | 933.03 | 1,025.20 | 1,088.14 | 1,187.15 |
| Administrative costs | 87.72 | 111.35 | 137.59 | 167.79 | 186.39 | 206.71 | 227.16 | 255.75 |
| *Salaries, wages* | *26.41* | *29.29* | *32.94* | *37.86* | *42.98* | *49.18* | *56.09* | *67.05* |
| *Social costs etc. (on salaries)* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Materials and services* | *34.22* | *41.92* | *48.26* | *55.35* | *60.81* | *66.88* | *73.47* | *85.13* |
| *Rents, leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Management costs* | *27.10* | *40.14* | *56.39* | *74.57* | *82.60* | *90.65* | *97.59* | *103.56* |
| OPERATING COSTS | 426.62 | 582.96 | 786.38 | 1,015.89 | 1,119.42 | 1,231.90 | 1,315.30 | 1,442.90 |
| Depreciation | 206.40 | 192.07 | 192.31 | 177.95 | 153.39 | 162.41 | 171.38 | 176.15 |
| Financial costs | 28.77 | 29.92 | 31.12 | 25.89 | 20.19 | 14.00 | 7.28 | 0.00 |
| *Interest* | *28.77* | *29.92* | *31.12* | *25.89* | *20.19* | *14.00* | *7.28* | *0.00* |
| *Leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |

**ANNUAL COSTS OF PRODUCTS - TOTAL**
US Dollar ('000)

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| TOTAL PRODUCTION COSTS | 661.79 | 804.95 | 1,009.81 | 1,219.72 | 1,293.01 | 1,408.31 | 1,493.96 | 1,619.04 |
| Direct marketing costs | 17.80 | 26.32 | 36.98 | 48.91 | 54.16 | 59.43 | 63.98 | 67.89 |
| *Salaries, wages* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Rents, leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Other direct costs* | *17.80* | *26.32* | *36.98* | *48.91* | *54.16* | *59.43* | *63.98* | *67.89* |
| COSTS OF PRODUCTS | 679.59 | 831.27 | 1,046.79 | 1,268.63 | 1,347.17 | 1,467.74 | 1,557.94 | 1,686.94 |
| Unit cost | 0.80 | 0.73 | 0.68 | 0.65 | 0.65 | 0.68 | 0.69 | 0.74 |
| Foreign share (%) | 27.98 | 25.44 | 22.07 | 20.20 | 17.50 | 17.66 | 17.33 | 16.30 |
| Variable share (%) | 48.29 | 57.01 | 63.73 | 69.72 | 72.33 | 72.98 | 72.99 | 73.15 |

**PRODUCTION AND SALES PROGRAMME - TOTAL**
US Dollar ('000)

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| *Stock brought forward* | 0.00 | 31.81 | 44.02 | 59.42 | 75.44 | 79.84 | 84.23 | 87.15 |
| Quantity produced | 849.81 | 1,144.21 | 1,543.40 | 1,956.02 | 2,057.39 | 2,170.39 | 2,243.92 | 2,286.71 |
| Stock carried over | 31.81 | 44.02 | 59.42 | 75.44 | 79.84 | 84.23 | 87.15 | 88.86 |
| Quantity sold | 818.00 | 1,132.00 | 1,528.00 | 1,940.00 | 2,053.00 | 2,166.00 | 2,241.00 | 2,285.00 |
| Gross unit price (average) | 0.70 | 0.73 | 0.76 | 0.79 | 0.82 | 0.86 | 0.89 | 0.93 |
| Gross sales revenue | 575.57 | 828.36 | 1,162.87 | 1,535.48 | 1,689.91 | 1,854.24 | 1,995.19 | 2,115.73 |
| Less sales tax | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Net sales revenue | 575.57 | 828.36 | 1,162.87 | 1,535.48 | 1,689.91 | 1,854.24 | 1,995.19 | 2,115.73 |
| *Subsidy* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SALES REVENUE | 575.57 | 828.36 | 1,162.87 | 1,535.48 | 1,689.91 | 1,854.24 | 1,995.19 | 2,115.73 |
| Foreign share (%) | 48.98 | 48.98 | 48.98 | 48.98 | 48.98 | 48.98 | 48.98 | 48.98 |

**FINANCIAL FLOW - TOTAL**
US Dollar ('000)

| | Total inflow | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Scrap 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total equity capital | 702.72 | 382.15 | 264.44 | 56.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ordinary capital* | *301.52* | *123.08* | *122.32* | *56.13* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| In kind | 150.00 | 100.00 | 50.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cash | 151.53 | 23.08 | 72.31 | 56.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Preference capital* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| In kind | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cash | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Subsidies, grants* | *401.19* | 259.07 | *142.12* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Total long-term loans | 675.93 | 0.00 | 325.24 | 350.69 | 0.00 | 0.00 | -155.58 | -161.80 | -168.27 | -175.00 | -182.00 | 0.00 | 0.00 |
| *Supplier credit* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Development finance institutions* | *675.93* | *0.00* | *325.24* | *350.69* | *0.00* | *0.00* | *-155.58* | *-161.80* | *-168.27* | *-175.00* | *-182.00* | *0.00* | *0.00* |
| *Commercial banks* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Government loans* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Others* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| TOTAL LONG-TERM FINANCE | 1,378.65 | 382.15 | 589.68 | 406.82 | 0.00 | 0.00 | -155.58 | -161.80 | -168.27 | -175.00 | -182.00 | 0.00 | 0.00 |
| Total short-term finance | 43.74 | 0.00 | 0.00 | 0.00 | 14.63 | 4.65 | 5.82 | 6.46 | 3.06 | 3.22 | 2.85 | 3.06 | -43.74 |
| *Total short-term loans* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Accounts payable* | *43.74* | *0.00* | *0.00* | *0.00* | *14.63* | *4.65* | *5.82* | *6.46* | *3.06* | *3.22* | *2.85* | *3.06* | *-43.74* |
| TOTAL FINANCIAL FLOW | 1,422.39 | 382.15 | 589.68 | 406.82 | 14.63 | 4.65 | -149.76 | -155.34 | -165.22 | -171.78 | -179.16 | 3.06 | -43.74 |
| Foreign share (%) | 76.51 | 67.79 | 79.26 | 86.20 | 24.66 | 25.92 | 102.86 | 103.07 | 101.35 | 101.39 | 101.18 | 21.23 | 25.35 |

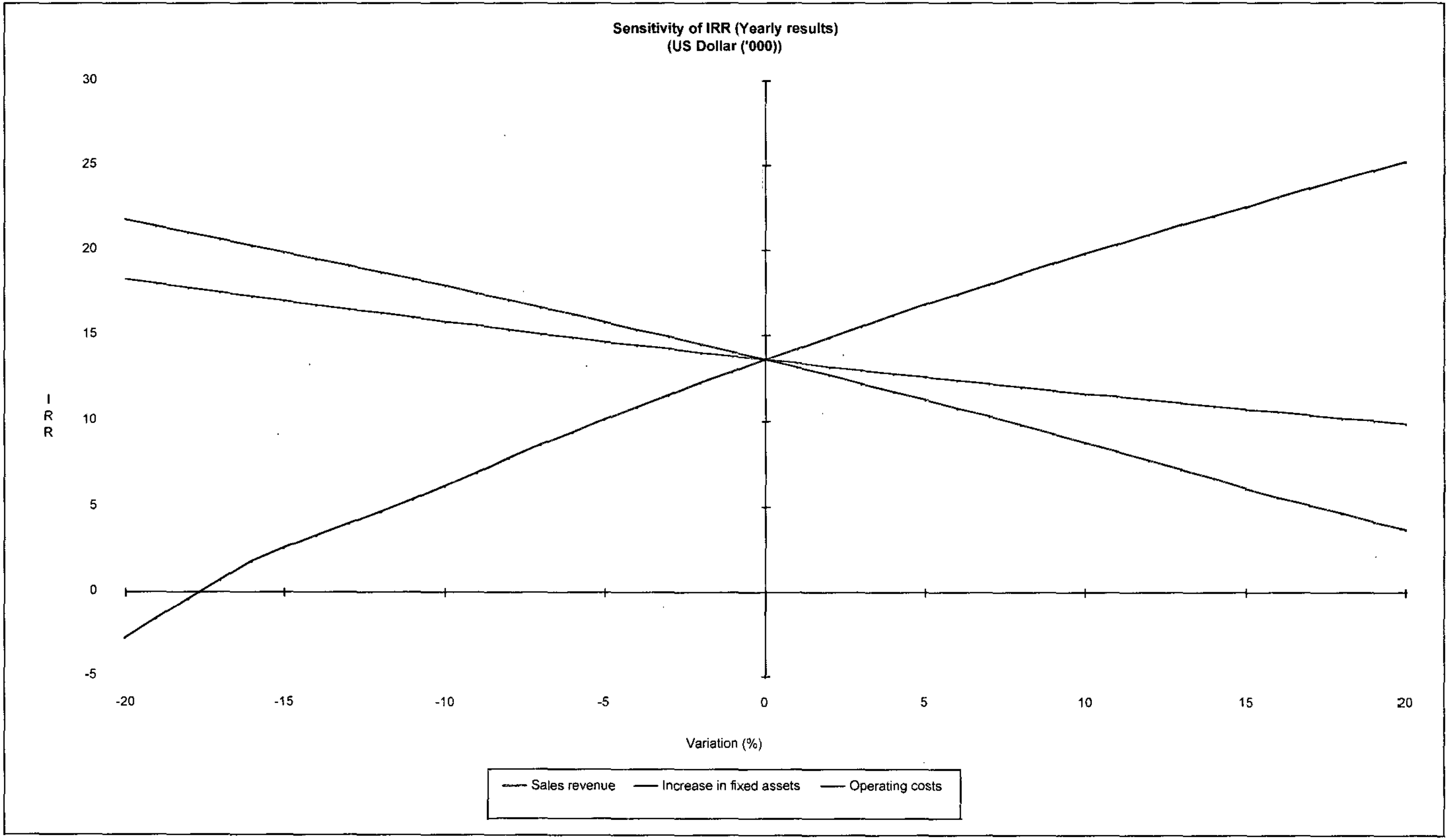
## CASH FLOW FOR FINANCIAL PLANNING - TOTAL

US Dollar ('000)

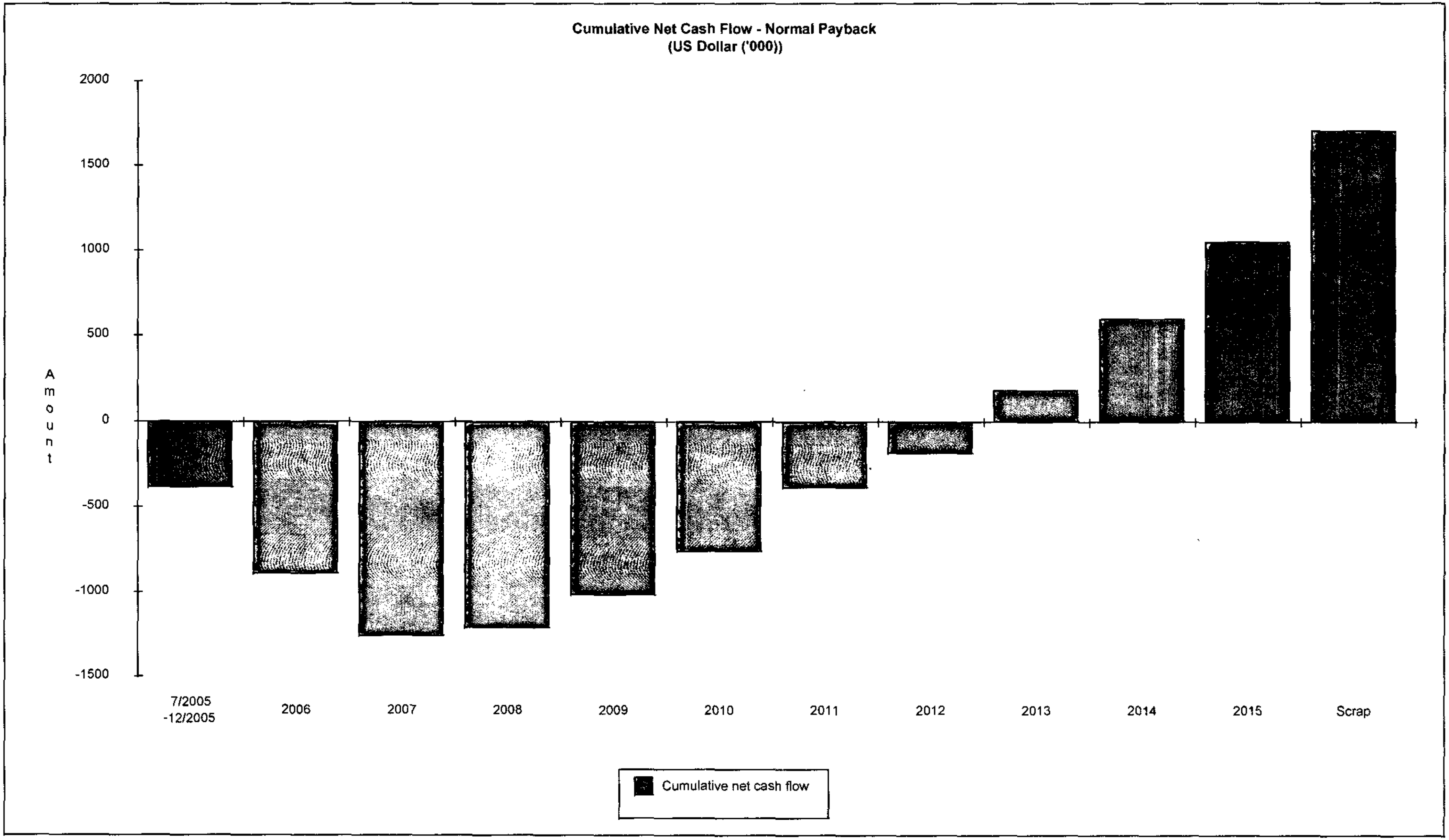
| | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Scrap 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL CASH INFLOW | 382.15 | 589.68 | 406.82 | 590.19 | 833.01 | 1,168.69 | 1,541.93 | 1,692.97 | 1,857.46 | 1,998.03 | 2,118.79 | 691.01 |
| Inflow funds | 382.15 | 589.68 | 406.82 | 14.63 | 4.65 | 5.82 | 6.46 | 3.06 | 3.22 | 2.85 | 3.06 | 0.00 |
| *Total equity capital* | *382.15* | *264.44* | *56.13* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Total long-term loans* | *0.00* | *325.24* | *350.69* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Total short-term finance* | *0.00* | *0.00* | *0.00* | *14.63* | *4.65* | *5.82* | *6.46* | *3.06* | *3.22* | *2.85* | *3.06* | *0.00* |
| Inflow operation | 0.00 | 0.00 | 0.00 | 575.57 | 828.36 | 1,162.87 | 1,535.48 | 1,689.91 | 1,854.24 | 1,995.19 | 2,115.73 | 0.00 |
| *Sales revenue* | *0.00* | *0.00* | *0.00* | *575.57* | *828.36* | *1,162.87* | *1,535.48* | *1,689.91* | *1,854.24* | *1,995.19* | *2,115.73* | *0.00* |
| *Interest on short-term deposits* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Other income | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 691.01 |
| TOTAL CASH OUTFLOW | 382.16 | 527.32 | 388.12 | 574.39 | 670.37 | 1,129.21 | 1,422.86 | 1,767.63 | 1,746.71 | 1,845.19 | 1,742.16 | 43.74 |
| Increase in fixed assets | 382.16 | 507.75 | 361.52 | 34.55 | 6.36 | 57.87 | 67.29 | 303.55 | 65.10 | 55.71 | 8.05 | 0.00 |
| *Fixed investments* | *382.16* | *481.40* | *333.91* | *34.55* | *6.36* | *57.87* | *67.29* | *303.55* | *65.10* | *55.71* | *8.05* | *0.00* |
| *Pre-production expenditures (net of interest)* | *0.00* | *26.35* | *27.61* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Increase in current assets | 0.00 | 0.00 | 0.00 | 66.65 | 24.81 | 32.26 | 36.37 | 16.34 | 17.69 | 13.22 | 19.65 | 0.00 |
| Operating costs | 0.00 | 0.00 | 0.00 | 426.62 | 582.96 | 786.38 | 1,015.89 | 1,119.42 | 1,231.90 | 1,315.30 | 1,442.90 | 0.00 |
| Marketing costs | 0.00 | 0.00 | 0.00 | 17.80 | 26.32 | 36.98 | 48.91 | 54.16 | 59.43 | 63.98 | 67.89 | 0.00 |
| Income (corporate) tax | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 115.95 | 131.17 | 128.64 | 0.00 |
| Financial costs | 0.00 | 19.57 | 26.60 | 28.77 | 29.92 | 31.12 | 25.89 | 20.19 | 14.00 | 7.28 | 0.00 | 0.00 |
| Loan repayment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 155.58 | 161.80 | 168.27 | 175.00 | 182.00 | 0.00 | 43.74 |
| Dividends | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 29.02 | 66.71 | 85.69 | 67.64 | 76.52 | 75.04 | 0.00 |
| Equity capital refund | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SURPLUS (DEFICIT) | 0.00 | 62.36 | 18.70 | 15.81 | 162.64 | 39.48 | 119.07 | -74.66 | 110.75 | 152.84 | 376.63 | 647.27 |
| CUMULATIVE CASH BALANCE | 0.00 | 62.36 | 81.05 | 96.86 | 259.50 | 298.98 | 418.05 | 343.39 | 454.15 | 606.99 | 983.62 | 1,630.89 |
| Foreign surplus (deficit) | 81.16 | 59.39 | 111.45 | 179.46 | 317.51 | 254.81 | 406.87 | 236.15 | 544.73 | 614.36 | 902.90 | 25.28 |
| Local surplus (deficit) | -81.17 | 2.97 | -92.76 | -163.65 | -154.87 | -215.33 | -287.80 | -310.81 | -433.98 | -461.52 | -526.27 | 621.99 |
| Foreign cumulative cash balance | 81.16 | 140.56 | 252.01 | 431.47 | 748.98 | 1,003.79 | 1,410.66 | 1,646.81 | 2,191.54 | 2,805.90 | 3,708.80 | 3,734.08 |
| Local cumulative cash balance | -81.17 | -78.20 | -170.96 | -334.61 | -489.48 | -704.81 | -992.61 | -1,303.42 | -1,737.40 | -2,198.91 | -2,725.19 | -2,103.19 |
| Net flow of funds | 382.15 | 570.10 | 380.22 | -14.14 | -25.27 | -209.89 | -247.94 | -271.10 | -253.42 | -262.96 | -71.98 | -43.74 |

**DISCOUNTED CASH FLOW - TOTAL CAPITAL INVESTED**
US Dollar ('000)

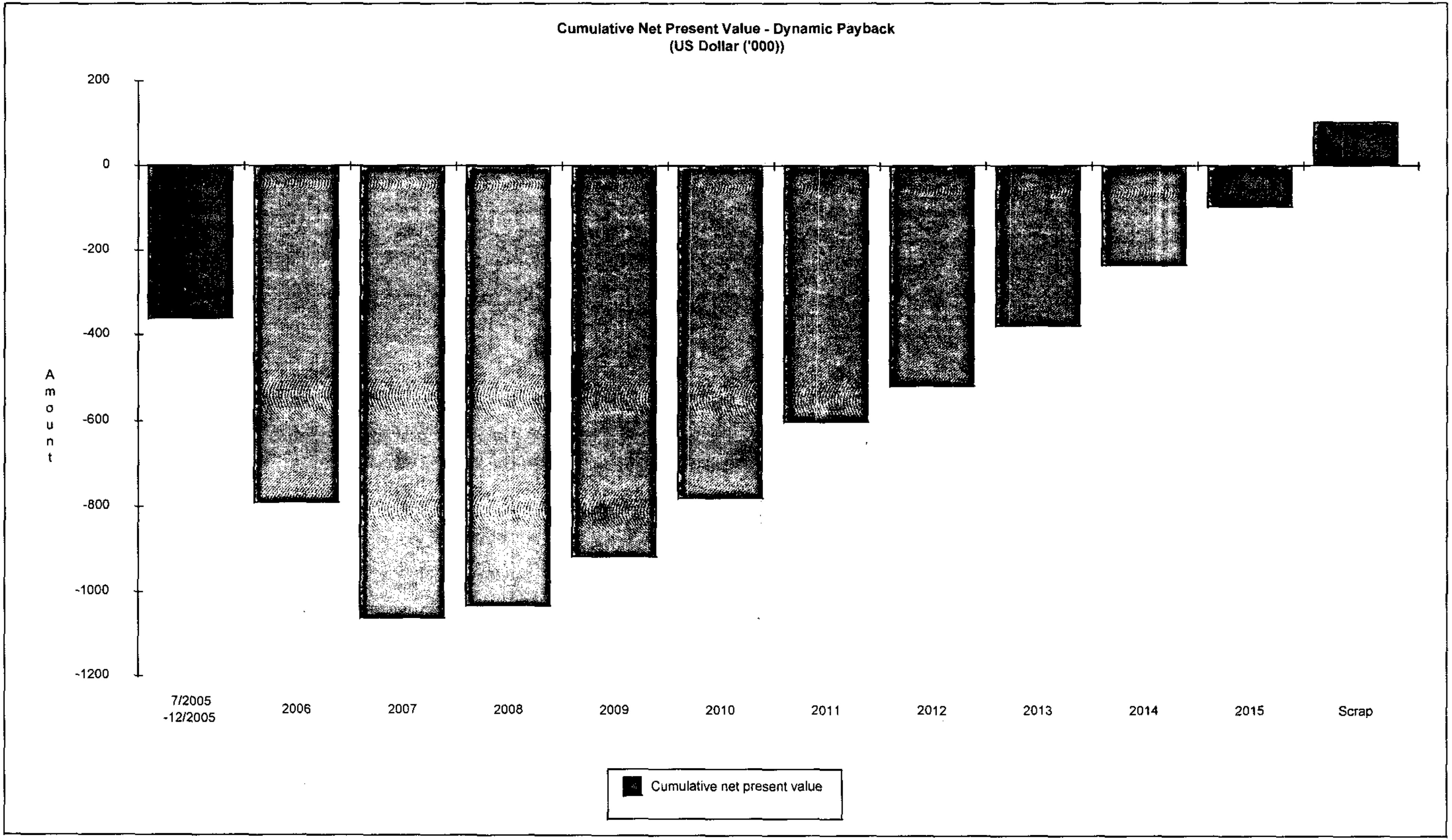
| | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Scrap 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL CASH INFLOW | 0.00 | 0.00 | 0.00 | 575.57 | 828.36 | 1,162.87 | 1,535.48 | 1,689.91 | 1,854.24 | 1,995.19 | 2,115.73 | 647.27 |
| Inflow operation | 0.00 | 0.00 | 0.00 | 575.57 | 828.36 | 1,162.87 | 1,535.48 | 1,689.91 | 1,854.24 | 1,995.19 | 2,115.73 | 0.00 |
| *Sales revenue* | *0.00* | *0.00* | *0.00* | *575.57* | *828.36* | *1,162.87* | *1,535.48* | *1,689.91* | *1,854.24* | *1,995.19* | *2,115.73* | *0.00* |
| *Interest on short-term deposits* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Other income | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 647.27 |
| TOTAL CASH OUTFLOW | 382.16 | 507.75 | 361.52 | 530.99 | 635.80 | 907.68 | 1,162.00 | 1,490.42 | 1,486.85 | 1,576.54 | 1,664.06 | 0.00 |
| Increase in fixed assets | 382.16 | 507.75 | 361.52 | 34.55 | 6.36 | 57.87 | 67.29 | 303.55 | 65.10 | 55.71 | 8.05 | 0.00 |
| *Fixed investments* | *382.16* | *481.40* | *333.91* | *34.55* | *6.36* | *57.87* | *67.29* | *303.55* | *65.10* | *55.71* | *8.05* | *0.00* |
| *Pre-production expenditures (net of interest)* | *0.00* | *26.35* | *27.61* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Increase in net working capital | 0.00 | 0.00 | 0.00 | 52.02 | 20.16 | 26.44 | 29.91 | 13.28 | 14.47 | 10.38 | 16.59 | 0.00 |
| Operating costs | 0.00 | 0.00 | 0.00 | 426.62 | 582.96 | 786.38 | 1,015.89 | 1,119.42 | 1,231.90 | 1,315.30 | 1,442.90 | 0.00 |
| Marketing costs | 0.00 | 0.00 | 0.00 | 17.80 | 26.32 | 36.98 | 48.91 | 54.16 | 59.43 | 63.98 | 67.89 | 0.00 |
| Income (corporate) tax | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 115.95 | 131.17 | 128.64 | 0.00 |
| NET CASH FLOW | -382.16 | -507.75 | -361.52 | 44.58 | 192.56 | 255.19 | 373.47 | 199.49 | 367.40 | 418.65 | 451.67 | 647.27 |
| CUMULATIVE NET CASH FLOW | -382.16 | -889.90 | -1,251.43 | -1,206.85 | -1,014.29 | -759.10 | -385.63 | -186.13 | 181.26 | 599.91 | 1,051.58 | 1,698.85 |
| Net present value | -361.10 | -428.37 | -272.33 | 29.98 | 115.63 | 136.82 | 178.79 | 85.27 | 140.21 | 142.65 | 137.41 | 196.92 |
| Cumulative net present value | -361.10 | -789.48 | -1,061.80 | -1,031.82 | -916.19 | -779.36 | -600.57 | -515.30 | -375.09 | -232.44 | -95.03 | 101.90 |
| NET PRESENT VALUE | at 12.00% | 101.90 | | | | | | | | | | |
| INTERNAL RATE OF RETURN | 13.59% | | | | | | | | | | | |
| MODIFIED INTERNAL RATE OF RETURN | 13.59% | | | | | | | | | | | |
| NORMAL PAYBACK | at 0.00% | 8.51 years | = 2013 | | | | | | | | | |
| DYNAMIC PAYBACK | at 12.00% | 11.48 years | = 2016 | | | | | | | | | |
| NPV RATIO | 0.07 | | | | | | | | | | | |
| Net present values discounted to | 7/2005 | | | | | | | | | | | |


Sensitivity of IRR (Yearly results)
(US Dollar ('000))
30
25
20
15
10
5
0
-5
IRR
-20
-15
-10
-5
0
5
10
15
20
Variation (%)
Sales revenue
Increase in fixed assets
Operating costs

| Variation (%) | Sales revenue | Increase in fixed assets | Operating costs |
|---|---|---|---|
| -20.00 % | -2.75 % | 18.37 % | 21.83 % |
| -16.00 % | 1.79 % | 17.30 % | 20.30 % |
| -12.00 % | 4.73 % | 16.30 % | 18.72 % |
| -8.00 % | 7.81 % | 15.35 % | 17.08 % |
| -4.00 % | 10.81 % | 14.45 % | 15.38 % |
| 0.00 % | 13.59 % | 13.59 % | 13.59 % |
| 4.00 % | 16.19 % | 12.78 % | 11.73 % |
| 8.00 % | 18.63 % | 12.00 % | 9.77 % |
| 12.00 % | 20.93 % | 11.25 % | 7.71 % |
| 16.00 % | 23.11 % | 10.54 % | 5.57 % |
| 20.00 % | 25.18 % | 9.85 % | 3.66 % |


Cumulative Net Cash Flow - Normal Payback
(US Dollar ('000))
2000
1500
1000
500
0
-500
-1000
-1500
Amount
7/2005 -12/2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Scrap
Cumulative net cash flow

| | Cumulative net cash flow |
|---|---|
| 7/2005-12/2005 | -382.16 |
| 2006 | -889.90 |
| 2007 | -1,251.43 |
| 2008 | -1,206.85 |
| 2009 | -1,014.29 |
| 2010 | -759.10 |
| 2011 | -385.63 |
| 2012 | -186.13 |
| 2013 | 181.26 |
| 2014 | 599.91 |
| 2015 | 1,051.58 |
| Scrap | 1,698.85 |


Cumulative Net Present Value - Dynamic Payback
(US Dollar ('000))
200
0
-200
-400
-600
-800
-1000
-1200
Amount
7/2005 -12/2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Scrap
Cumulative net present value

| | Cumulative net present value |
|---|---|
| 7/2005-12/2005 | -361.10 |
| 2006 | -789.48 |
| 2007 | -1,061.80 |
| 2008 | -1,031.82 |
| 2009 | -916.19 |
| 2010 | -779.36 |
| 2011 | -600.57 |
| 2012 | -515.30 |
| 2013 | -375.09 |
| 2014 | -232.44 |
| 2015 | -95.03 |
| Scrap | 101.90 |

**DISCOUNTED CASH FLOW - EQUITY CAPITAL INVESTED**
US Dollar ('000)

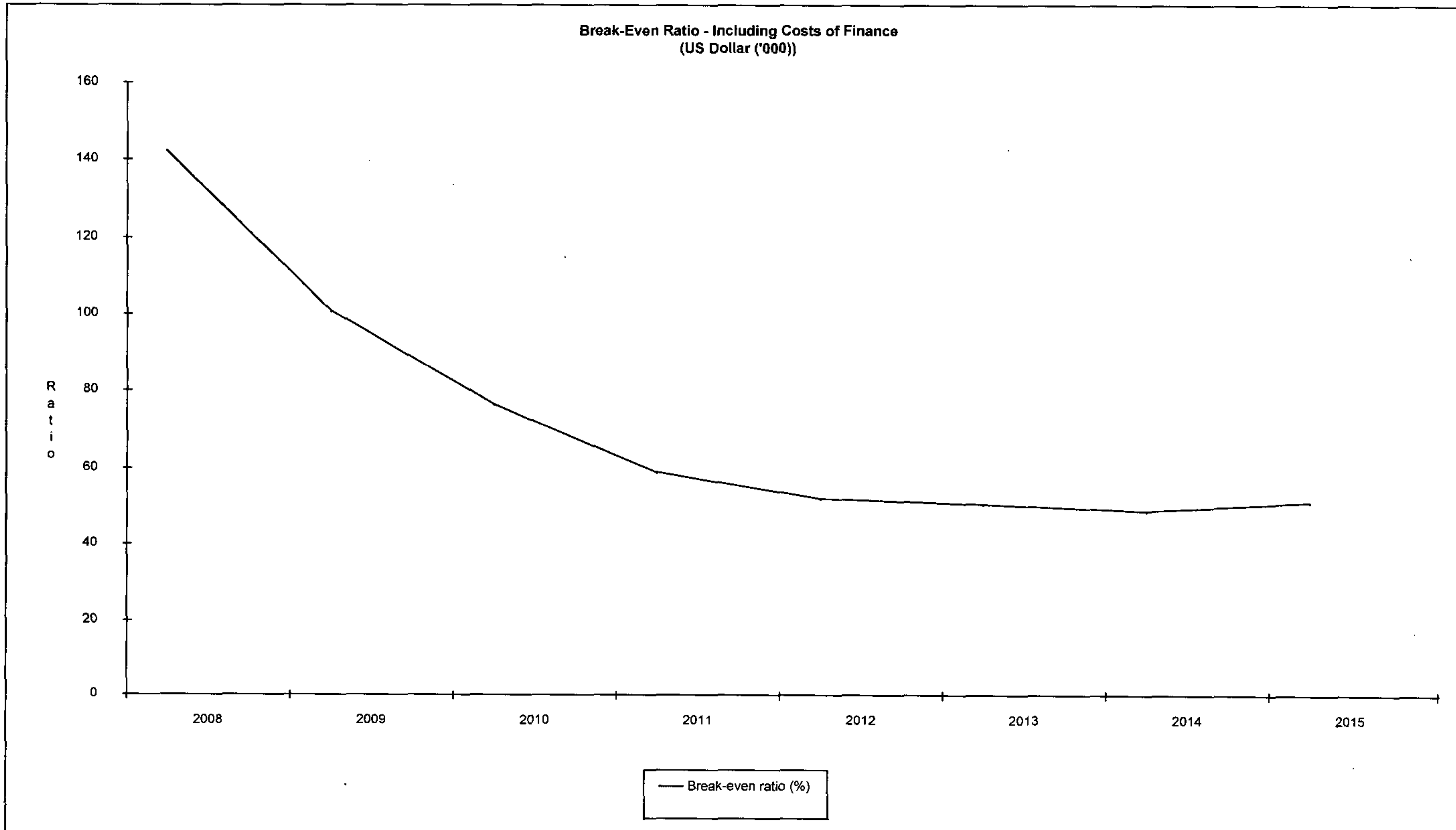
| | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Scrap 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL CASH INFLOW | 0.00 | 62.36 | 18.70 | 15.81 | 162.64 | 68.50 | 185.78 | 11.03 | 178.39 | 229.36 | 451.67 | 647.27 |
| Surplus (deficit) | *0.00* | 62.36 | *18.70* | *15.81* | 162.64 | 39.48 | 119.07 | -74.66 | 110.75 | 152.84 | 376.63 | 647.27 |
| Dividends | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 29.02 | 66.71 | 85.69 | 67.64 | 76.52 | 75.04 | 0.00 |
| Equity capital refund | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL CASH OUTFLOW | 123.08 | 122.32 | 56.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Equity capital paid | 123.08 | 122.32 | 56.13 | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | 0.00 | 0.00 | 0.00 |
| NET CASH RETURN | -123.08 | -59.96 | -37.43 | 15.81 | 162.64 | 68.50 | 185.78 | 11.03 | 178.39 | 229.36 | 451.67 | 647.27 |
| CUMULATIVE NET CASH RETURN | -123.08 | -183.04 | -220.47 | -204.67 | -42.02 | 26.47 | 212.26 | 223.28 | 401.67 | 631.04 | 1,082.71 | 1,729.98 |
| Net present value | -112.36 | -45.61 | -23.73 | 8.35 | 71.60 | 25.13 | 56.80 | 2.81 | 37.87 | 40.58 | 66.59 | 95.43 |
| Cumulative net present value | -112.36 | -157.97 | -181.70 | -173.35 | -101.75 | -76.62 | -19.82 | -17.01 | *20.86* | 61.44 | 128.03 | *223.46* |
| NET PRESENT VALUE | at 20.00% | 223.46 | | | | | | | | | | |
| INTERNAL RATE OF RETURN | 35.10% | | | | | | | | | | | |
| MODIFIED INTERNAL RATE OF RETURN | 35.10% | | | | | | | | | | | |
| SHORT NET PRESENT VALUE | at 20.00% | 128.03 | for 11 years | | | | | | | | | |
| NORMAL PAYBACK | at 0.00% | 5.61 years | ≈ 2010 | | | | | | | | | |
| DYNAMIC PAYBACK | at 20.00% | 8.45 years | ≈ 2013 | | | | | | | | | |
| *NPV RATIO* | 0.93 | | | | | | | | | | | |
| Net present values discounted to | 7/2005 | | | | | | | | | | | |

**NET INCOME STATEMENT**
US Dollar ('000)

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| Sales revenue | 575.57 | 828.36 | 1,162.87 | 1,535.48 | 1,689.91 | 1,854.24 | 1,995.19 | 2,115.73 |
| Less variable costs | 328.17 | 473.90 | 667.07 | 884.48 | 974.38 | 1,071.10 | 1,137.10 | 1,234.03 |
| *Material* | *271.74* | *391.21* | *551.02* | *730.73* | *803.18* | *880.54* | *929.03* | *996.95* |
| *Personnel* | *11.53* | *16.24* | *22.68* | *30.27* | *34.45* | *40.48* | *46.50* | *65.63* |
| *Marketing (except personnel)* | *17.80* | *26.32* | *36.98* | *48.91* | *54.16* | *59.43* | *63.98* | *67.89* |
| *Other variable costs* | *27.10* | *40.14* | *56.39* | *74.57* | *82.60* | *90.65* | *97.59* | *103.56* |
| VARIABLE MARGIN | 247.39 | 354.46 | 495.80 | 650.99 | 715.53 | 783.14 | 858.09 | 881.70 |
| in % of sales revenue | 42.98 | 42.79 | 42.64 | 42.40 | 42.34 | 42.24 | 43.01 | 41.67 |
| Less fixed costs | 322.65 | 327.45 | 348.61 | 358.26 | 352.59 | 382.64 | 413.56 | 452.90 |
| *Material* | *48.77* | *57.06* | *64.01* | *71.73* | *77.84* | *84.59* | *91.89* | *104.29* |
| *Personnel* | *26.41* | *29.29* | *32.94* | *37.86* | *42.98* | *49.18* | *56.09* | *67.05* |
| *Marketing (except personnel)* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Depreciation* | *206.40* | *192.07* | *192.31* | *177.95* | *153.39* | *162.41* | *171.38* | *176.15* |
| *Other fixed costs* | *41.07* | *49.03* | *59.35* | *70.73* | *78.38* | *86.46* | *94.20* | *105.42* |
| OPERATIONAL MARGIN | -75.26 | 27.01 | 147.19 | 292.73 | 362.94 | 400.51 | 444.53 | 428.80 |
| in % of sales revenue | -13.08 | 3.26 | 12.66 | 19.06 | 21.48 | 21.60 | 22.28 | 20.27 |
| Interest on short-term deposits | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Financial costs | 28.77 | 29.92 | 31.12 | 25.89 | 20.19 | 14.00 | 7.28 | 0.00 |
| GROSS PROFIT FROM OPERATIONS | -104.03 | -2.91 | 116.08 | 266.84 | 342.74 | 386.51 | 437.24 | 428.80 |
| in % of sales revenue | -18.07 | -0.35 | 9.98 | 17.38 | 20.28 | 20.84 | 21.92 | 20.27 |
| Extraordinary income | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Extraordinary loss | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Depreciation allowances | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| GROSS PROFIT | -104.03 | -2.91 | 116.08 | 266.84 | 342.74 | 386.51 | 437.24 | 428.80 |
| Investment allowances | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Deductible loss | 0.00 | 0.00 | 106.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TAXABLE PROFIT | 0.00 | 0.00 | 9.14 | 266.84 | 342.74 | 386.51 | 437.24 | 428.80 |
| Income (corporate) tax | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 115.95 | 131.17 | 128.64 |
| NET PROFIT | -104.03 | -2.91 | 116.08 | 266.84 | 342.74 | 270.55 | 306.07 | 300.16 |
| in % of sales revenue | -18.07 | -0.35 | 9.98 | 17.38 | 20.28 | 14.59 | 15.34 | 14.19 |
| Dividends | 0.00 | 0.00 | 29.02 | 66.71 | 85.69 | 67.64 | 76.52 | 75.04 |
| RETAINED PROFIT | -104.03 | -2.91 | 87.06 | 200.13 | 257.06 | 202.92 | 229.55 | 225.12 |
| RATIOS | | | | | | | | |
| Net profit to equity (%) | -34.50 | -0.96 | 38.50 | 88.50 | 113.67 | 89.73 | 101.51 | 99.55 |
| Net profit to net worth (%) | -18.73 | -0.56 | 19.98 | 35.29 | 34.49 | 22.87 | 21.77 | 18.40 |
| Net profit+interest to investment (%) | -5.44 | 1.91 | 9.85 | 18.39 | 19.01 | 14.31 | 15.25 | 14.44 |

**BREAK-EVEN ANALYSIS - TOTAL**
US Dollar ('000)

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| Sales revenue | 575.57 | 828.36 | 1,162.87 | 1,535.48 | 1,689.91 | 1,854.24 | 1,995.19 | 2,115.73 |
| Variable costs | 328.17 | 473.90 | 667.07 | 884.48 | 974.38 | 1,071.10 | 1,137.10 | 1,234.03 |
| Variable margin | 247.39 | 354.46 | 495.80 | 650.99 | 715.53 | 783.14 | 858.09 | 881.70 |
| Variable margin ratio (%) | 42.98 | 42.79 | 42.64 | 42.40 | 42.34 | 42.24 | 43.01 | 41.67 |
| Including cost of finance | | | | | | | | |
| *Fixed costs* | 322.65 | 327.45 | 348.61 | 358.26 | 352.59 | 382.64 | 413.56 | 452.90 |
| Financial costs | 28.77 | 29.92 | 31.12 | 25.89 | 20.19 | 14.00 | 7.28 | 0.00 |
| Break-even sales value | 817.58 | 835.16 | 890.62 | 906.08 | 880.42 | 939.12 | 978.53 | 1,086.79 |
| Break-even ratio (%) | 142.05 | 100.82 | 76.59 | 59.01 | 52.10 | 50.65 | 49.04 | 51.37 |
| Fixed costs coverage ratio | 0.70 | 0.99 | 1.31 | 1.69 | 1.92 | 1.97 | 2.04 | 1.95 |
| Excluding cost of finance | | | | | | | | |
| Fixed costs | 322.65 | 327.45 | 348.61 | 358.26 | 352.59 | 382.64 | 413.56 | 452.90 |
| *Break-even sales value* | 750.65 | 765.24 | 817.64 | 845.02 | 832.73 | 905.97 | 961.60 | 1,086.79 |
| Break-even ratio (%) | 130.42 | 92.38 | 70.31 | 55.03 | 49.28 | 48.86 | 48.20 | 51.37 |
| Fixed costs coverage ratio | 0.77 | 1.08 | 1.42 | 1.82 | 2.03 | 2.05 | 2.07 | 1.95 |


Break-Even Ratio - Including Costs of Finance
(US Dollar ('000))
160
140
120
100
80
60
40
20
0
Ratio
2008
2009
2010
2011
2012
2013
2014
2015
Break-even ratio (%)

| | Break-even ratio (%) |
|---|---|
| 2008 | 142.05 |
| 2009 | 100.82 |
| 2010 | 76.59 |
| 2011 | 59.01 |
| 2012 | 52.10 |
| 2013 | 50.65 |
| 2014 | 49.04 |
| 2015 | 51.37 |

**PROJECTED BALANCE SHEET**
US Dollar ('000)

| | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL ASSETS | 382.16 | 971.83 | 1,394.26 | 1,436.55 | 1,469.97 | 1,437.19 | 1,419.81 | 1,511.19 | 1,555.79 | 1,613.18 | 1,841.36 |
| Total current assets | 0.00 | 62.36 | 81.05 | 163.51 | 350.96 | 422.70 | 578.14 | 519.82 | 648.27 | 814.34 | 1,210.61 |
| *Inventory on materials & supplies* | *0.00* | *0.00* | *0.00* | *2.51* | *3.61* | *5.07* | *6.70* | *7.37* | *8.09* | *8.65* | *9.21* |
| *Work in progress* | *0.00* | *0.00* | *0.00* | *0.94* | *1.31* | *1.80* | *2.36* | *2.59* | *2.85* | *3.02* | *3.30* |
| *Finished product* | *0.00* | *0.00* | *0.00* | *16.59* | *22.67* | *30.58* | *39.51* | *43.53* | *47.91* | *51.15* | *56.11* |
| *Accounts receivable* | *0.00* | *0.00* | *0.00* | *46.29* | *63.47* | *85.77* | *110.92* | *122.25* | *134.51* | *143.67* | *157.37* |
| *Cash-in-hand* | *0.00* | *0.00* | *0.00* | *0.32* | *0.40* | *0.50* | *0.61* | *0.69* | *0.77* | *0.85* | *1.00* |
| *Short-term deposits* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Cash surplus, finance available* | 0.00 | 62.36 | 81.05 | *96.86* | *259.50* | *298.98* | *418.05* | *343.39* | *454.15* | *606.99* | *983.62* |
| Total fixed assets, net of depreciation | 382.16 | 909.48 | 1,297.60 | 1,125.74 | 940.04 | 805.60 | 694.94 | 845.10 | 747.79 | 632.12 | 464.02 |
| *Fixed investments* | *0.00* | *382.16* | *863.55* | *1,197.46* | *1,232.01* | *1,238.37* | *1,296.24* | *1,363.53* | *1,667.09* | *1,732.19* | *1,787.89* |
| *Construction in progress* | *382.16* | *481.40* | *333.91* | *34.55* | *6.36* | *57.87* | *67.29* | 303.55 | 65.10 | 55.71 | 8.05 |
| *Total pre-production expenditures* | *0.00* | *45.92* | *100.14* | *100.14* | *100.14* | *100.14* | *100.14* | *100.14* | *100.14* | *100.14* | *100.14* |
| *Less accumulated depreciation* | *0.00* | *0.00* | *0.00* | *206.40* | *398.47* | *590.78* | *768.73* | *922.12* | *1,084.53* | *1,255.91* | *1,432.06* |
| *Less depreciation allowance* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Accumulated losses brought forward | 0.00 | 0.00 | 0.00 | 0.00 | 104.03 | 106.93 | 19.88 | 0.00 | 0.00 | 0.00 | 0.00 |
| Loss in current year | 0.00 | 0.00 | 0.00 | 104.03 | 2.91 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exchange rate losses | 0.00 | 0.00 | 15.61 | 43.27 | 72.04 | 101.96 | 126.85 | 146.27 | 159.73 | 166.73 | 166.73 |
| TOTAL LIABILITIES | 382.15 | 971.83 | 1,394.26 | 1,436.55 | 1,469.97 | 1,437.19 | 1,419.81 | 1,511.19 | 1,555.79 | 1,613.18 | 1,841.36 |
| Total current liabilities | 0.00 | 0.00 | 0.00 | 14.63 | 19.28 | 25.10 | 31.56 | 34.61 | 37.83 | 40.68 | 43.74 |
| *Accounts payable* | *0.00* | *0.00* | *0.00* | *14.63* | *19.28* | *25.10* | *31.56* | *34.61* | *37.83* | *40.68* | *43.74* |
| *Total short-term debt* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Total long-term debt | 0.00 | 325.24 | 691.54 | 719.20 | 747.97 | 622.31 | 485.40 | 336.55 | 175.00 | 0.00 | 0.00 |
| Total equity capital | 382.15 | 646.59 | 702.72 | 702.72 | 702.72 | 702.72 | 702.72 | 702.72 | 702.72 | 702.72 | 702.72 |
| *Ordinary capital* | *123.08* | *245.39* | *301.52* | *301.52* | *301.52* | *301.52* | *301.52* | *301.52* | *301.52* | *301.52* | *301.52* |
| *Preference capital* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Subsidies, grants* | *259.07* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* |
| Reserves, retained profit brought forward | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 180.26 | 437.32 | 640.23 | 869.78 |
| Retained profit | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 87.06 | 200.13 | 257.06 | 202.92 | 229.55 | 225.12 |
| Net worth | 382.15 | 646.59 | 687.11 | 555.42 | 523.75 | 580.88 | 756.12 | 993.77 | 1,183.22 | 1,405.77 | 1,630.89 |
| RATIOS | | | | | | | | | | | |
| Equity to total liabilities (%) | 100.00 | 66.53 | 50.40 | 48.92 | 47.81 | 48.90 | 49.49 | 46.50 | 45.17 | 43.56 | 38.16 |
| Net worth to total liabilities (%) | 100.00 | 66.53 | 49.28 | 38.66 | 35.63 | 40.42 | 53.26 | 65.76 | 76.05 | 87.14 | 88.57 |
| Long-term debt to net worth | 0.00 | 0.50 | 1.01 | 1.29 | 1.43 | 1.07 | 0.64 | 0.34 | 0.15 | 0.00 | 0.00 |
| Current assets to current liabilities | 0.00 | 0.00 | 0.00 | 11.18 | 18.20 | 16.84 | 18.32 | 15.02 | 17.13 | 20.02 | 27.68 |

## SUMMARY SHEET

| | |
|---|---|
| Project title: | Sisal Fibre Extraction Project |
| Project description: | The Project will involve growing of sisal by smallholders and outgrowers on 1,890 hectares who will in turn sell sisal leaves to the project for processing. Three hammer mills will process sisal leaves and boles to produce pulpable fibre for local and export market. Domestic inflation rate is expected to average 5.4% in 2006 due to food shortages caused by drought but fall to the previous 4.8% in 2007 and thereafter remain at around 4.0% . |
| Date and time: | 30 NOVEMBER 2005 |
| Project classification: | New project |
| Construction phase: | 7/2005 - 12/2007 |
| Length: | 2 years, 6 months |
| Production phase: | 1/2008 - 12/2015 |
| Length: | 8 years |
| Accounting currency: | US Dollar('000) (US$) |
| Units: | Absolute |
| Local currency: | Tanzania Shillings ('000) (TSH) |
| Exchange rate: | 1.0000 US$ = 1,200.0000 TSH |

INVESTMENT COSTS

| | Total construction | Total production | Total investment |
|---|---|---|---|
| Total fixed investment costs | 1,953.70 | 881.15 | 2,834.85 |
| Total pre-production expenditures | 126.78 | 0.00 | 126.78 |
| *Pre-production expenditures (net of interest)* | *53.96* | *0.00* | *53.96* |
| *Interest* | *72.81* | *0.00* | *72.81* |
| Increase in net working capital | 0.00 | 360.48 | 360.48 |
| TOTAL INVESTMENT COSTS | 2,080.48 | 1,241.63 | 3,322.11 |

SOURCES OF FINANCE

| | Total construction | Total production | Total inflow |
|---|---|---|---|
| Total equity capital | 1,014.93 | 0.00 | 1,014.93 |
| *Foreign* | *401.19* | *0.00* | *401.19* |
| *Local* | *613.74* | *0.00* | *613.74* |
| Total long-term loans | 1,111.53 | 0.00 | 1,111.53 |
| *Foreign* | *1,111.53* | *0.00* | *1,111.53* |
| *Local* | *0.00* | *0.00* | *0.00* |
| Total short-term loans | 0.00 | 0.00 | 0.00 |
| *Foreign* | *0.00* | *0.00* | *0.00* |
| *Local* | *0.00* | *0.00* | *0.00* |
| Accounts payable | 0.00 | 87.27 | 87.27 |
| TOTAL SOURCES OF FINANCE | 2,126.46 | 87.27 | 2,213.73 |

INCOME AND COSTS, OPERATIONS

| | First year | Reference year | Last year |
|---|---|---|---|

## SUMMARY SHEET

| | 2008 | 2008 | 2015 |
|---|---|---|---|
| SALES REVENUE | 1,151.13 | 1,151.13 | 4,232.39 |
| Factory costs | 698.04 | 698.04 | 2,451.41 |
| Administrative overhead costs | 120.79 | 120.79 | 391.18 |
| OPERATING COSTS | 818.83 | 818.83 | 2,842.59 |
| Depreciation | 310.83 | 310.83 | 276.65 |
| Financial costs | 47.03 | 47.03 | 0.00 |
| TOTAL PRODUCTION COSTS | 1,176.69 | 1,176.69 | 3,119.24 |
| Marketing costs | 35.60 | 35.60 | 135.78 |
| COSTS OF PRODUCTS | 1,212.29 | 1,212.29 | 3,255.02 |
| Interest on short-term deposits | 0.00 | 0.00 | 0.00 |
| GROSS PROFIT FROM OPERATIONS | -61.16 | -61.16 | 977.37 |
| Extraordinary income | 0.00 | 0.00 | 0.00 |
| Extraordinary loss | 0.00 | 0.00 | 0.00 |
| Depreciation allowances | 0.00 | 0.00 | 0.00 |
| GROSS PROFIT | -61.16 | -61.16 | 977.37 |
| Investment allowances | 0.00 | 0.00 | 0.00 |
| TAXABLE PROFIT | 0.00 | 0.00 | 977.37 |
| Income (corporate) tax | 0.00 | 0.00 | 293.21 |
| NET PROFIT | -61.16 | -61.16 | 684.16 |

RATIOS

| | | |
|---|---|---|
| Net Present Value of Total Capital Invested | at 12.00% | 780.14 |
| Internal rate of return on investment (IRR) | 19.13% | |
| Modified IRR on investment | 19.13% | |
| Net Present Value of Total Equity Capital Invested | at 20.00% | 533.43 |
| Internal rate of return on equity (IRRE) | 34.82% | |
| Modified IRRE on equity | 34.82% | |
| Net present values discounted to | 7/2005 | |

**FIXED INVESTMENT COSTS - TOTAL**

US Dollar('000)

| | Total construction | Total production | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Land purchase | 157.68 | 112.73 | 0.00 | 143.57 | 14.12 | 12.23 | 12.72 | 13.23 | 13.76 | 14.31 | 14.89 | 15.48 | 16.10 |
| *Land purchase* | *105.40* | *0.00* | *0.00* | *105.40* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Land preparation* | *27.00* | *58.22* | *0.00* | *19.71* | *7.29* | *6.32* | *6.57* | *6.83* | *7.11* | *7.39* | *7.69* | *7.99* | *8.31* |
| *Planting costs* | *8.84* | *19.05* | *0.00* | *6.45* | *2.39* | *2.07* | *2.15* | *2.24* | *2.33* | *2.42* | *2.52* | *2.62* | *2.72* |
| *Field maintenance* | *11.54* | *24.87* | *0.00* | *8.42* | *3.11* | *2.70* | *2.81* | *2.92* | *3.04* | *3.16* | *3.28* | *3.42* | *3.55* |
| *Soil analysis* | *4.91* | *10.59* | *0.00* | *3.58* | *1.33* | *1.15* | *1.19* | *1.24* | *1.29* | *1.34* | *1.40* | *1.45* | *1.51* |
| Site preparation and development | 29.20 | 0.00 | 0.00 | 1.58 | 27.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Civil works, structures and buildings | 457.58 | 0.00 | 329.64 | 17.71 | 110.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Plant machinery and equipment | 1,097.77 | 698.56 | 177.91 | 470.40 | 449.46 | 25.85 | 44.80 | 78.28 | 103.38 | 339.34 | 52.41 | 54.51 | 0.00 |
| *Mill Machinery & Equipment* | *675.49* | *22.37* | *95.19* | *237.99* | *342.31* | *0.00* | *0.00* | *22.37* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Farm Tractors, Vehicles & Equipment* | *319.76* | *560.83* | *75.00* | *228.19* | *16.57* | *25.85* | *44.80* | *55.91* | *98.21* | *229.14* | *52.41* | *54.51* | *0.00* |
| *Laboratory & Office Equipment* | *102.52* | *115.37* | *7.73* | *4.22* | *90.58* | *0.00* | *0.00* | *0.00* | *5.17* | *110.20* | *0.00* | *0.00* | *0.00* |
| Auxiliary and service plant equipment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Environmental protection | 26.51 | 0.00 | 0.00 | 0.00 | 26.51 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Site preparation* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Civil works* | *26.51* | *0.00* | *0.00* | *0.00* | *26.51* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Plant machinery and equipment* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Incorporated fixed assets (project overheads) | 74.61 | 0.00 | 74.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Technology* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Project implementation* | *74.61* | *0.00* | *74.61* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Miscellaneous project overhead costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Contingencies | 110.35 | 69.86 | 0.00 | 48.97 | 61.38 | 2.58 | 4.48 | 7.83 | 10.34 | 33.93 | 5.24 | 5.45 | 0.00 |
| *Mill Machinery & Equipment* | *58.03* | *2.24* | *0.00* | *23.80* | *34.23* | *0.00* | *0.00* | *2.24* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Farm Tractors, Vehicles & Implements* | *24.48* | *56.08* | *0.00* | *22.82* | *1.66* | *2.58* | *4.48* | *5.59* | *9.82* | *22.91* | *5.24* | *5.45* | *0.00* |
| *Laboratory & Office Equipment* | *9.48* | *11.54* | *0.00* | *0.42* | *9.06* | *0.00* | *0.00* | *0.00* | *0.52* | *11.02* | *0.00* | *0.00* | *0.00* |
| *Environmental Protection* | *2.65* | *0.00* | *0.00* | *0.00* | *2.65* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Civil Structures/Site Preparation* | *15.71* | *0.00* | *0.00* | *1.93* | *13.79* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| TOTAL FIXED INVESTMENT COSTS | 1,953.70 | 881.15 | 582.16 | 682.22 | 689.32 | 40.67 | 62.01 | 99.34 | 127.48 | 387.58 | 72.54 | 75.44 | 16.10 |
| Foreign share (%) | 60.90 | 87.21 | 30.56 | 75.85 | 71.72 | 69.92 | 79.48 | 86.68 | 89.20 | 96.31 | 79.48 | 79.48 | 0.00 |

**PRE-PRODUCTION EXPENDITURES - TOTAL**
US Dollar('000)

| | Total construction | Total production | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pre-investment studies | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Preparatory investigations | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Company formation, fees etc. | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Project management, organization | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Technology acquisition | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Detailed engineering, contracting | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pre-production supplies, marketing | 53.96 | 0.00 | 0.00 | 26.35 | 27.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other capital (issue) expenditures | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Contingencies | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Pre-production expenditures (net of interest) | 53.96 | 0.00 | 0.00 | 26.35 | 27.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Interest | 72.81 | 0.00 | 0.00 | 29.33 | 43.48 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL PRE-PRODUCTION EXPENDITURES | 126.78 | 0.00 | 0.00 | 55.68 | 71.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Foreign share (%) | 57.43 | 0.00 | 0.00 | 52.68 | 61.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**NET WORKING CAPITAL REQUIREMENTS - TOTAL**
US Dollar('000)

| | Coefficient of turnover | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total inventory | 0.00 | 0.00 | 0.00 | 0.00 | 38.81 | 54.08 | 74.18 | 96.76 | 106.53 | 117.11 | 124.84 | 135.83 |
| *Raw materials* | *0.00* | *0.00* | *0.00* | *0.00* | *1.29* | *1.85* | *2.61* | *3.47* | *3.81* | *4.17* | *4.39* | *4.72* |
| Leaf Purchase | 360.00 | 0.00 | 0.00 | 0.00 | 1.29 | 1.85 | 2.61 | 3.47 | 3.81 | 4.17 | 4.39 | 4.72 |
| *Factory supplies* | *0.00* | *0.00* | *0.00* | *0.00* | *3.74* | *5.38* | *7.56* | *9.98* | *10.98* | *12.05* | *12.97* | *13.75* |
| Hammer Milling | 12.00 | 0.00 | 0.00 | 0.00 | 0.41 | 0.59 | 0.83 | 1.09 | 1.20 | 1.32 | 1.42 | 1.50 |
| Drying | 12.00 | 0.00 | 0.00 | 0.00 | 3.31 | 4.77 | 6.70 | 8.84 | 9.73 | 10.68 | 11.49 | 12.19 |
| Baling/stacking | 360.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.03 | 0.04 | 0.05 | 0.05 | 0.06 | 0.06 |
| *Utilities* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Water | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Energy* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Energy kWh | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Energy KVA/Fees | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Spare parts consumed* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Work in progress* | *360.00* | *0.00* | *0.00* | *0.00* | *1.94* | *2.71* | *3.73* | *4.88* | *5.37* | *5.89* | *6.26* | *6.81* |
| *Finished product* | *25.71* | *0.00* | *0.00* | *0.00* | *31.84* | *44.14* | *60.28* | *78.44* | *86.37* | *94.98* | *101.23* | *110.55* |
| Accounts receivable | 0.00 | 0.00 | 0.00 | 0.00 | 89.00 | 123.70 | 169.18 | 220.28 | 242.64 | 266.80 | 284.48 | 310.25 |
| Cash-in-hand | 360.00 | 0.00 | 0.00 | 0.00 | 0.47 | 0.62 | 0.81 | 1.03 | 1.15 | 1.29 | 1.42 | 1.67 |
| CURRENT ASSETS | 0.00 | 0.00 | 0.00 | 0.00 | 128.28 | 178.40 | 244.18 | 318.07 | 350.32 | 385.20 | 410.74 | 447.75 |
| Accounts payable | 0.00 | 0.00 | 0.00 | 0.00 | 28.28 | 37.65 | 49.72 | 63.12 | 69.23 | 75.73 | 81.37 | 87.27 |
| *Raw materials* | *0.00* | *0.00* | *0.00* | *0.00* | *1.29* | *1.85* | *2.61* | *3.47* | *3.81* | *4.17* | *4.39* | *4.72* |
| Leaf Purchase | 360.00 | 0.00 | 0.00 | 0.00 | 1.29 | 1.85 | 2.61 | 3.47 | 3.81 | 4.17 | 4.39 | 4.72 |
| *Factory supplies* | *0.00* | *0.00* | *0.00* | *0.00* | *4.05* | *5.51* | *7.72* | *10.15* | *11.04* | *12.11* | *13.00* | *13.78* |
| Hammer Milling | 12.00 | 0.00 | 0.00 | 0.00 | 0.44 | 0.60 | 0.84 | 1.11 | 1.21 | 1.32 | 1.42 | 1.51 |
| Drying | 12.00 | 0.00 | 0.00 | 0.00 | 3.59 | 4.88 | 6.84 | 9.00 | 9.78 | 10.73 | 11.52 | 12.21 |
| Baling/stacking | 360.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.03 | 0.04 | 0.05 | 0.05 | 0.06 | 0.06 |
| *Utilities* | *0.00* | *0.00* | *0.00* | *0.00* | *0.02* | *0.02* | *0.02* | *0.02* | *0.02* | *0.02* | *0.02* | *0.02* |
| Water | 12.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| *Energy* | *0.00* | *0.00* | *0.00* | *0.00* | *6.92* | *9.17* | *12.12* | *15.40* | *16.81* | *18.31* | *19.62* | *20.75* |
| Energy kWh | 12.00 | 0.00 | 0.00 | 0.00 | 4.93 | 7.10 | 9.97 | 13.16 | 14.48 | 15.90 | 17.10 | 18.14 |
| Energy KVA/Fees | 12.00 | 0.00 | 0.00 | 0.00 | 1.99 | 2.07 | 2.15 | 2.24 | 2.33 | 2.42 | 2.52 | 2.62 |
| *Spare parts consumed* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Repair, maintenance, material* | *0.00* | *0.00* | *0.00* | *0.00* | *4.84* | *5.48* | *6.28* | *7.12* | *7.72* | *8.33* | *8.89* | *9.42* |
| Repair, maintenance estate | 0.00 | 0.00 | 0.00 | 0.00 | 2.19 | 2.54 | 3.00 | 3.46 | 3.84 | 4.22 | 4.56 | 4.89 |
| *Estate Maintenance Labour* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Estate Maintenance Non-labour* | *12.00* | *0.00* | *0.00* | *0.00* | *2.19* | *2.54* | *3.00* | *3.46* | *3.84* | *4.22* | *4.56* | *4.89* |
| Repair, maintenance mill | 0.00 | 0.00 | 0.00 | 0.00 | 2.22 | 2.47 | 2.78 | 3.12 | 3.31 | 3.51 | 3.70 | 3.88 |
| *Mill Maintenance Labour* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Mill Maintenance Non-labour* | *12.00* | *0.00* | *0.00* | *0.00* | *2.22* | *2.47* | *2.78* | *3.12* | *3.31* | *3.51* | *3.70* | *3.88* |
| Repair, maintenance Buildings/Roads | 12.00 | 0.00 | 0.00 | 0.00 | 0.43 | 0.46 | 0.50 | 0.54 | 0.57 | 0.60 | 0.63 | 0.66 |
| *Royalties* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Labour* | *0.00* | *0.00* | *0.00* | *0.00* | *0.02* | *0.03* | *0.05* | *0.06* | *0.07* | *0.09* | *0.10* | *0.14* |
| Hammer Milling | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Drying | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Baling/Stacking | 360.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.05 | 0.06 | 0.07 | 0.09 | 0.10 | 0.14 |
| *Labour overhead costs (taxes etc.)* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Factory overhead costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.25* | *0.23* | *0.22* | *0.21* | *0.21* | *0.18* | *0.15* | *0.11* |
| Salaries, wages | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

**NET WORKING CAPITAL REQUIREMENTS - TOTAL**
US Dollar('000)

| | Coefficient of turnover | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Social costs etc. (on salaries) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Materials and services | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Rents, leasing costs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Insurance | 12.00 | 0.00 | 0.00 | 0.00 | 0.23 | 0.20 | 0.18 | 0.15 | 0.15 | 0.11 | 0.07 | 0.03 |
| Cess | 360.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.03 | 0.04 | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 |
| *Administrative costs* | *0.00* | *0.00* | *0.00* | *0.00* | *7.92* | *10.98* | *14.54* | *18.54* | *20.52* | *22.61* | *24.54* | *27.01* |
| Salaries, wages | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Social costs etc. (on salaries) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Materials and services | 12.00 | 0.00 | 0.00 | 0.00 | 3.40 | 4.29 | 5.14 | 6.11 | 6.76 | 7.50 | 8.27 | 9.75 |
| Rents, leasing costs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Management costs | 12.00 | 0.00 | 0.00 | 0.00 | 4.52 | 6.69 | 9.40 | 12.43 | 13.77 | 15.11 | 16.26 | 17.26 |
| *Leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Direct marketing costs* | 0.00 | *0.00* | *0.00* | *0.00* | *2.97* | *4.39* | *6.16* | *8.15* | *9.03* | *9.91* | *10.66* | *11.32* |
| Salaries, wages | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Rents, leasing costs | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other direct costs | 12.00 | 0.00 | 0.00 | 0.00 | 2.97 | 4.39 | 6.16 | 8.15 | 9.03 | 9.91 | 10.66 | 11.32 |
| CURRENT LIABILITIES | 0.00 | 0.00 | 0.00 | 0.00 | 28.28 | 37.65 | 49.72 | 63.12 | 69.23 | 75.73 | 81.37 | 87.27 |
| TOTAL NET WORKING CAPITAL REQUIREMENTS | 0.00 | 0.00 | 0.00 | 0.00 | 100.01 | 140.75 | 194.45 | 254.95 | 281.09 | 309.47 | 329.37 | 360.48 |
| INCREASE IN NET WORKING CAPITAL | 0.00 | 0.00 | 0.00 | 0.00 | 100.01 | 40.75 | 53.70 | 60.50 | 26.14 | 28.37 | 19.90 | 31.11 |
| Foreign share (%) | 0.00 | 0.00 | 0.00 | 0.00 | 4.05 | 3.45 | 3.02 | 2.73 | 2.71 | 2.67 | 2.69 | 2.61 |

**INVESTMENT COSTS - TOTAL**

US Dollar('000)

| | Total construction | Total production | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total fixed investment costs | 1,953.70 | 881.15 | 582.16 | 682.22 | 689.32 | 40.67 | 62.01 | 99.34 | 127.48 | 387.58 | 72.54 | 75.44 | 16.10 |
| Total pre-production expenditures | 126.78 | 0.00 | 0.00 | 55.68 | 71.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Pre-production expenditures (net of interest)* | *53.96* | *0.00* | *0.00* | *26.35* | *27.61* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Interest* | *72.81* | *0.00* | *0.00* | *29.33* | *43.48* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Increase in net working capital* | 0.00 | 360.48 | 0.00 | 0.00 | 0.00 | 100.01 | 40.75 | 53.70 | 60.50 | 26.14 | 28.37 | 19.90 | 31.11 |
| TOTAL INVESTMENT COSTS | 2,080.48 | 1,241.63 | 582.16 | 737.90 | 760.42 | 140.67 | 102.75 | 153.04 | 187.98 | 413.72 | 100.91 | 95.34 | 47.21 |
| Foreign share (%) | 60.69 | 62.65 | 30.56 | 74.10 | 70.74 | 23.09 | 48.75 | 56.93 | 61.08 | 90.38 | 57.78 | 63.51 | 1.14 |

**ANNUAL COSTS OF PRODUCTS - TOTAL**
US Dollar('000)

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| Capacity utilization (%) | 37.18 | 50.06 | 67.53 | 85.56 | 90.02 | 94.99 | 98.16 | 100.08 |
| Raw materials | 463.29 | 666.98 | 939.96 | 1,247.51 | 1,370.81 | 1,502.63 | 1,580.02 | 1,698.99 |
| *Leaf Purchase* | *463.29* | *666.98* | *939.96* | *1,247.51* | *1,370.81* | *1,502.63* | *1,580.02* | *1,698.99* |
| Factory supplies | 50.67 | 72.92 | 102.38 | 135.16 | 148.80 | 163.28 | 175.64 | 186.30 |
| *Hammer Milling* | *4.91* | *7.07* | *9.92* | *13.09* | *14.41* | *15.82* | *17.02* | *18.05* |
| *Drying* | *39.78* | *57.25* | *80.38* | *106.11* | *116.82* | *128.18* | *137.89* | *146.26* |
| *Baling/stacking* | *5.98* | *8.61* | *12.09* | *15.96* | *17.57* | *19.28* | *20.74* | *21.99* |
| Utilities | 0.20 | 0.21 | 0.22 | 0.23 | 0.24 | 0.24 | 0.25 | 0.26 |
| *Water* | *0.20* | *0.21* | *0.22* | *0.23* | *0.24* | *0.24* | *0.25* | *0.26* |
| Energy | 83.07 | 110.01 | 145.42 | 184.74 | 201.74 | 219.78 | 235.39 | 249.05 |
| *Energy kWh* | *59.20* | *85.19* | *119.61* | *157.89* | *173.82* | *190.74* | *205.19* | *217.64* |
| *Energy KVA/Fees* | *23.87* | *24.82* | *25.81* | *26.85* | *27.92* | *29.04* | *30.20* | *31.41* |
| Spare parts consumed | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Repair, maintenance, material | 70.13 | 80.94 | 94.79 | 109.91 | 121.11 | 133.60 | 145.80 | 163.87 |
| *Repair, maintenance estate* | *31.93* | *37.35* | *44.26* | *51.39* | *57.55* | *64.19* | *70.57* | *80.35* |
| Estate Maintenance Labour | 5.66 | 6.82 | 8.30 | 9.92 | 11.51 | 13.60 | 15.80 | 21.71 |
| Estate Maintenance Non-labour | 26.27 | 30.53 | 35.96 | 41.47 | 46.05 | 50.60 | 54.77 | 58.64 |
| *Repair, maintenance mill* | *33.04* | *38.03* | *44.51* | *51.99* | *56.70* | *62.18* | *67.66* | *75.61* |
| Mill Maintenance Labour | 6.41 | 8.40 | 11.15 | 14.53 | 16.95 | 20.02 | 23.26 | 29.08 |
| Mill Maintenance Non-labour | 26.62 | 29.63 | 33.37 | 37.46 | 39.74 | 42.16 | 44.40 | 46.53 |
| *Repair, maintenance Buildings/Roads* | *5.16* | *5.55* | *6.02* | *6.52* | *6.86* | *7.22* | *7.57* | *7.91* |
| Royalties | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Labour | 20.39 | 29.57 | 42.22 | 57.14 | 65.20 | 76.83 | 88.39 | 124.88 |
| *Hammer Milling* | *10.39* | *14.80* | *20.87* | *28.00* | *31.90* | *37.53* | *43.13* | *60.90* |
| *Drying* | *1.97* | *2.96* | *4.34* | *5.97* | *6.83* | *8.08* | *9.31* | *13.16* |
| *Baling/Stacking* | *8.03* | *11.80* | *17.01* | *23.17* | *26.47* | *31.23* | *35.95* | *50.81* |
| Labour overhead costs (taxes etc.) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Factory overhead costs | 10.29 | 13.27 | 17.37 | 21.87 | 23.90 | 25.62 | 26.98 | 28.05 |
| *Salaries, wages* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Social costs etc. (on salaries)* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Materials and services* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | 0.00 | 0.00 | 0.00 |
| *Rents, leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Insurance* | *2.74* | *2.42* | *2.15* | *1.79* | *1.80* | *1.36* | *0.89* | *0.38* |
| *Cess* | *7.54* | *10.84* | *15.22* | *20.08* | *22.10* | *24.25* | *26.09* | *27.67* |
| FACTORY COSTS | 698.04 | 973.90 | 1,342.37 | 1,756.55 | 1,931.79 | 2,121.97 | 2,252.48 | 2,451.41 |
| Administrative costs | 120.79 | 161.01 | 207.81 | 260.35 | 289.25 | 320.46 | 350.54 | 391.18 |
| *Salaries, wages* | *25.77* | *29.29* | *33.31* | *37.86* | *42.98* | *49.18* | *56.09* | *67.05* |
| *Social costs etc. (on salaries)* | *0.00* | 0.00 | 0.00 | 0.00 | 0.00 | *0.00* | *0.00* | *0.00* |
| *Materials and services* | *40.82* | *51.45* | *61.72* | *73.35* | *81.07* | *89.99* | *99.28* | *117.00* |
| *Rents, leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Management costs* | *54.20* | *80.27* | *112.77* | *149.15* | *165.20* | *181.30* | *195.17* | *207.12* |
| OPERATING COSTS | 818.83 | 1,134.91 | 1,550.18 | 2,016.91 | 2,221.04 | 2,442.43 | 2,603.02 | 2,842.59 |
| Depreciation | 310.83 | 276.47 | 286.82 | 277.22 | 254.87 | 270.81 | 275.14 | 276.65 |
| Financial costs | 47.03 | 48.91 | 50.87 | 42.32 | 33.01 | 22.89 | 11.90 | 0.00 |
| *Interest* | *47.03* | *48.91* | *50.87* | *42.32* | *33.01* | *22.89* | *11.90* | *0.00* |
| *Leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |

**ANNUAL COSTS OF PRODUCTS - TOTAL**
*US Dollar('000)*

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| TOTAL PRODUCTION COSTS | 1,176.69 | 1,460.29 | 1,887.86 | 2,336.45 | 2,508.92 | 2,736.13 | 2,890.07 | 3,119.24 |
| Direct marketing costs | 35.60 | 52.65 | 73.97 | 97.81 | 108.31 | 118.86 | 127.95 | 135.78 |
| *Salaries, wages* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Rents, leasing costs* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Other direct costs* | *35.60* | *52.65* | *73.97* | *97.81* | *108.31* | *118.86* | *127.95* | *135.78* |
| COSTS OF PRODUCTS | 1,212.29 | 1,512.94 | 1,961.83 | 2,434.26 | 2,617.23 | 2,854.99 | 3,018.02 | 3,255.02 |
| *Unit cost* | 0.71 | 0.66 | 0.64 | 0.62 | 0.64 | 0.66 | 0.67 | 0.71 |
| Foreign share (%) | 25.18 | 22.28 | 19.34 | 17.22 | 15.45 | 15.34 | 14.78 | 13.79 |
| Variable share (%) | 56.37 | 65.28 | 70.90 | 75.78 | 77.64 | 78.24 | 78.61 | 78.98 |

**PRODUCTION AND SALES PROGRAMME - TOTAL**
US Dollar('000)

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| Stock brought forward | 0.00 | 63.62 | 88.04 | 118.84 | 150.85 | 159.68 | 168.51 | 174.26 |
| Quantity produced | 1,699.62 | 2,288.42 | 3,086.80 | 3,911.01 | 4,114.83 | 4,341.83 | 4,486.76 | 4,574.50 |
| Stock carried over | 63.62 | 88.04 | 118.84 | 150.85 | 159.68 | 168.51 | 174.26 | 177.76 |
| Quantity sold | 1,636.00 | 2,264.00 | 3,056.00 | 3,879.00 | 4,106.00 | 4,333.00 | 4,481.00 | 4,571.00 |
| Gross unit price (average) | 0.70 | 0.73 | 0.76 | 0.79 | 0.82 | 0.86 | 0.89 | 0.93 |
| Gross sales revenue | 1,151.13 | 1,656.73 | 2,325.74 | 3,070.16 | 3,379.82 | 3,709.34 | 3,989.48 | 4,232.39 |
| Less sales tax | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Net sales revenue | 1,151.13 | 1,656.73 | 2,325.74 | 3,070.16 | 3,379.82 | 3,709.34 | 3,989.48 | 4,232.39 |
| Subsidy | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SALES REVENUE | 1,151.13 | 1,656.73 | 2,325.74 | 3,070.16 | 3,379.82 | 3,709.34 | 3,989.48 | 4,232.39 |
| Foreign share (%) | 48.98 | 48.98 | 48.98 | 48.98 | 48.98 | 48.98 | 48.98 | 48.98 |

**FINANCIAL FLOW - TOTAL**
US Dollar('000)

| | Total inflow | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Scrap 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total equity capital | 1,014.93 | 582.15 | 358.05 | 74.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Ordinary capital* | *613.74* | *323.08* | *215.93* | *74.73* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| In kind | 400.00 | 300.00 | 100.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cash | 213.74 | 23.08 | 115.93 | 74.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Preference capital* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| In kind | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cash | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Subsidies, grants* | *401.19* | *259.07* | *142.12* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Total long-term loans | 1,111.53 | 0.00 | 395.61 | 715.92 | 0.00 | 0.00 | -254.34 | -264.51 | -275.09 | -286.09 | -297.54 | 0.00 | 0.00 |
| *Supplier credit* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Development finance institutions* | *1,111.53* | *0.00* | *395.61* | *715.92* | *0.00* | *0.00* | *-254.34* | *-264.51* | *-275.09* | *-286.09* | *-297.54* | *0.00* | *0.00* |
| *Commercial banks* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Government loans* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Others* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| TOTAL LONG-TERM FINANCE | 2,126.46 | 582.15 | 753.66 | 790.65 | 0.00 | 0.00 | -254.34 | -264.51 | -275.09 | -286.09 | -297.54 | 0.00 | 0.00 |
| Total short-term finance | 87.27 | 0.00 | 0.00 | 0.00 | 28.28 | 9.38 | 12.07 | 13.39 | 6.11 | 6.50 | 5.64 | 5.90 | -87.27 |
| *Total short-term loans* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Accounts payable* | *87.27* | *0.00* | *0.00* | *0.00* | *28.28* | *9.38* | *12.07* | *13.39* | *6.11* | *6.50* | *5.64* | *5.90* | *-87.27* |
| TOTAL FINANCIAL FLOW | 2,213.73 | 582.15 | 753.66 | 790.65 | 28.28 | 9.38 | -242.26 | -251.12 | -268.98 | -279.60 | -291.89 | 5.90 | -87.27 |
| Foreign share (%) | 69.24 | 44.50 | 71.35 | 90.55 | 26.08 | 21.61 | 103.93 | 104.22 | 101.73 | 101.80 | 101.49 | 19.53 | 23.01 |

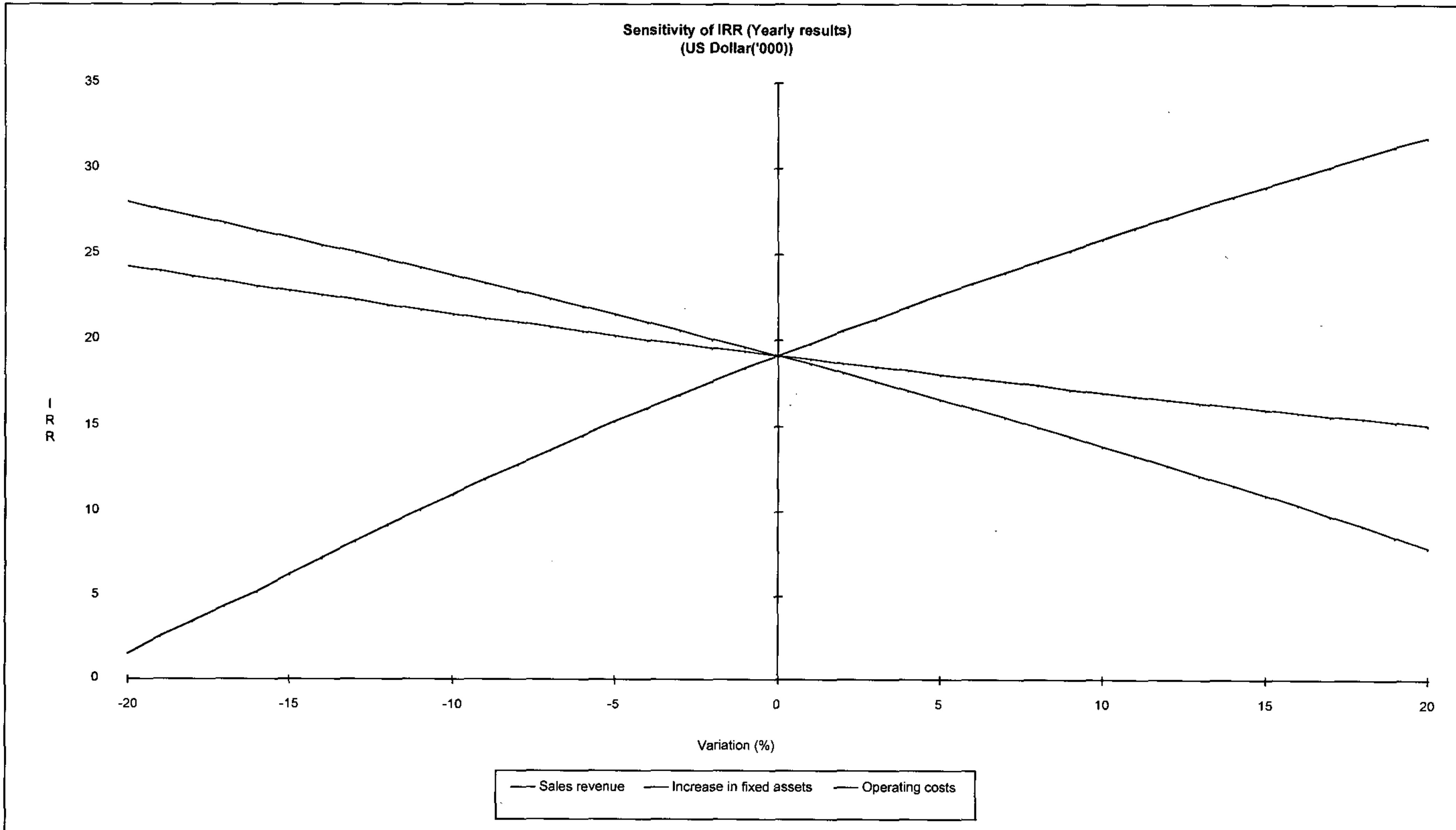
**CASH FLOW FOR FINANCIAL PLANNING - TOTAL**
US Dollar('000)

| | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Scrap 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL CASH INFLOW | 582.15 | 753.66 | 790.65 | 1,179.41 | 1,666.10 | 2,337.81 | 3,083.55 | 3,385.93 | 3,715.84 | 3,995.12 | 4,238.29 | 1,180.56 |
| Inflow funds | 582.15 | 753.66 | 790.65 | 28.28 | 9.38 | 12.07 | 13.39 | 6.11 | 6.50 | 5.64 | 5.90 | 0.00 |
| *Total equity capital* | *582.15* | *358.05* | *74.73* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Total long-term loans* | *0.00* | *395.61* | *715.92* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Total short-term finance* | *0.00* | *0.00* | *0.00* | *28.28* | *9.38* | *12.07* | *13.39* | *6.11* | *6.50* | *5.64* | *5.90* | *0.00* |
| Inflow operation | 0.00 | 0.00 | 0.00 | 1,151.13 | 1,656.73 | 2,325.74 | 3,070.16 | 3,379.82 | 3,709.34 | 3,989.48 | 4,232.39 | 0.00 |
| *Sales revenue* | *0.00* | *0.00* | *0.00* | *1,151.13* | *1,656.73* | *2,325.74* | *3,070.16* | *3,379.82* | *3,709.34* | *3,989.48* | *4,232.39* | *0.00* |
| *Interest on short-term deposits* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Other income | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1,180.56 |
| TOTAL CASH OUTFLOW | 582.16 | 737.90 | 760.42 | 1,070.41 | 1,384.55 | 2,185.44 | 2,781.90 | 3,247.93 | 3,383.50 | 3,602.84 | 3,495.73 | 87.27 |
| Increase in fixed assets | 582.16 | 708.57 | 716.94 | 40.67 | 62.01 | 99.34 | 127.48 | 387.58 | 72.54 | 75.44 | 16.10 | 0.00 |
| *Fixed investments* | *582.16* | *682.22* | *689.32* | *40.67* | *62.01* | *99.34* | *127.48* | *387.58* | *72.54* | *75.44* | *16.10* | *0.00* |
| *Pre-production expenditures (net of interest)* | *0.00* | *26.35* | *27.61* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Increase in current assets | 0.00 | 0.00 | 0.00 | 128.28 | 50.12 | 65.77 | 73.89 | 32.25 | 34.87 | 25.55 | 37.01 | 0.00 |
| Operating costs | 0.00 | 0.00 | 0.00 | 818.83 | 1,134.91 | 1,550.18 | 2,016.91 | 2,221.04 | 2,442.43 | 2,603.02 | 2,842.59 | 0.00 |
| Marketing costs | 0.00 | 0.00 | 0.00 | 35.60 | 52.65 | 73.97 | 97.81 | 108.31 | 118.86 | 127.95 | 135.78 | 0.00 |
| Income (corporate) tax | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 256.30 | 291.44 | 293.21 | 0.00 |
| Financial costs | 0.00 | 29.33 | 43.48 | 47.03 | 48.91 | 50.87 | 42.32 | 33.01 | 22.89 | 11.90 | 0.00 | 0.00 |
| Loan repayment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 254.34 | 264.51 | 275.09 | 286.09 | 297.54 | 0.00 | 87.27 |
| Dividends | 0.00 | 0.00 | 0.00 | 0.00 | 35.95 | 90.98 | 158.98 | 190.65 | 149.51 | 170.01 | 171.04 | 0.00 |
| Equity capital refund | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SURPLUS (DEFICIT) | 0.00 | 15.75 | 30.23 | 109.00 | 281.56 | 152.37 | 301.66 | 138.00 | 332.34 | 392.28 | 742.56 | 1,093.29 |
| CUMULATIVE CASH BALANCE | 0.00 | 15.75 | 45.99 | 154.99 | 436.55 | 588.92 | 890.58 | 1,028.58 | 1,360.91 | 1,753.19 | 2,495.76 | 3,589.05 |
| Foreign surplus (deficit) | 81.16 | -9.04 | 178.04 | 395.81 | 599.64 | 603.52 | 905.37 | 779.31 | 1,237.91 | 1,356.92 | 1,831.52 | 41.22 |
| Local surplus (deficit) | -81.17 | 24.80 | -147.80 | -286.81 | -318.09 | -451.15 | -603.71 | -641.31 | -905.58 | -964.64 | -1,088.96 | 1,052.07 |
| Foreign cumulative cash balance | 81.16 | 72.12 | 250.16 | 645.97 | 1,245.61 | 1,849.14 | 2,754.51 | 3,533.81 | 4,771.73 | 6,128.65 | 7,960.17 | 8,001.39 |
| Local cumulative cash balance | -81.17 | -56.37 | -204.17 | -490.98 | -809.07 | -1,260.22 | -1,863.93 | -2,505.24 | -3,410.81 | -4,375.45 | -5,464.41 | -4,412.34 |
| Net flow of funds | 582.15 | 724.33 | 747.17 | -18.75 | -75.48 | -384.11 | -452.41 | -492.64 | -451.99 | -473.80 | -165.14 | -87.27 |

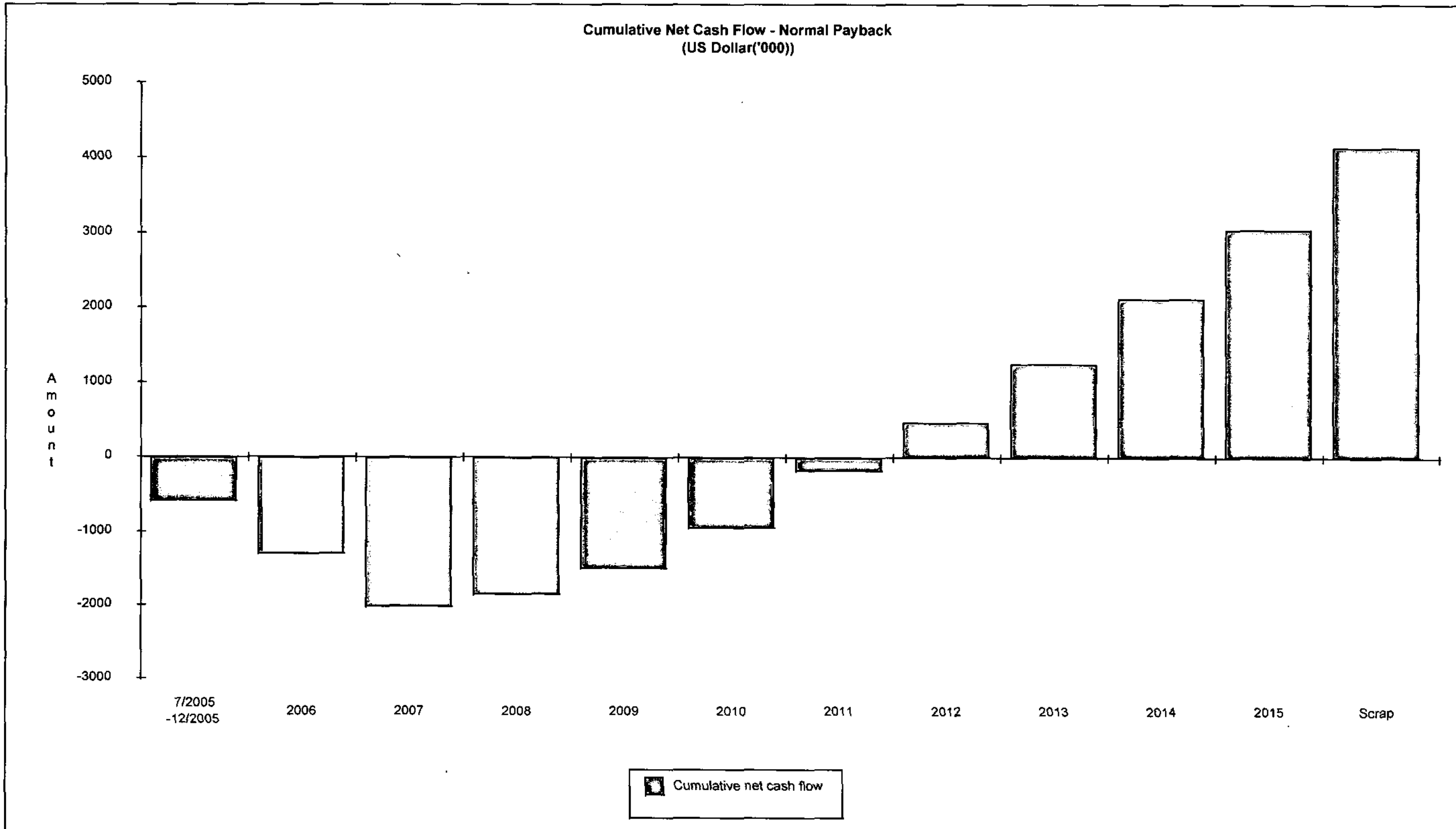
## DISCOUNTED CASH FLOW - TOTAL CAPITAL INVESTED

US Dollar('000)

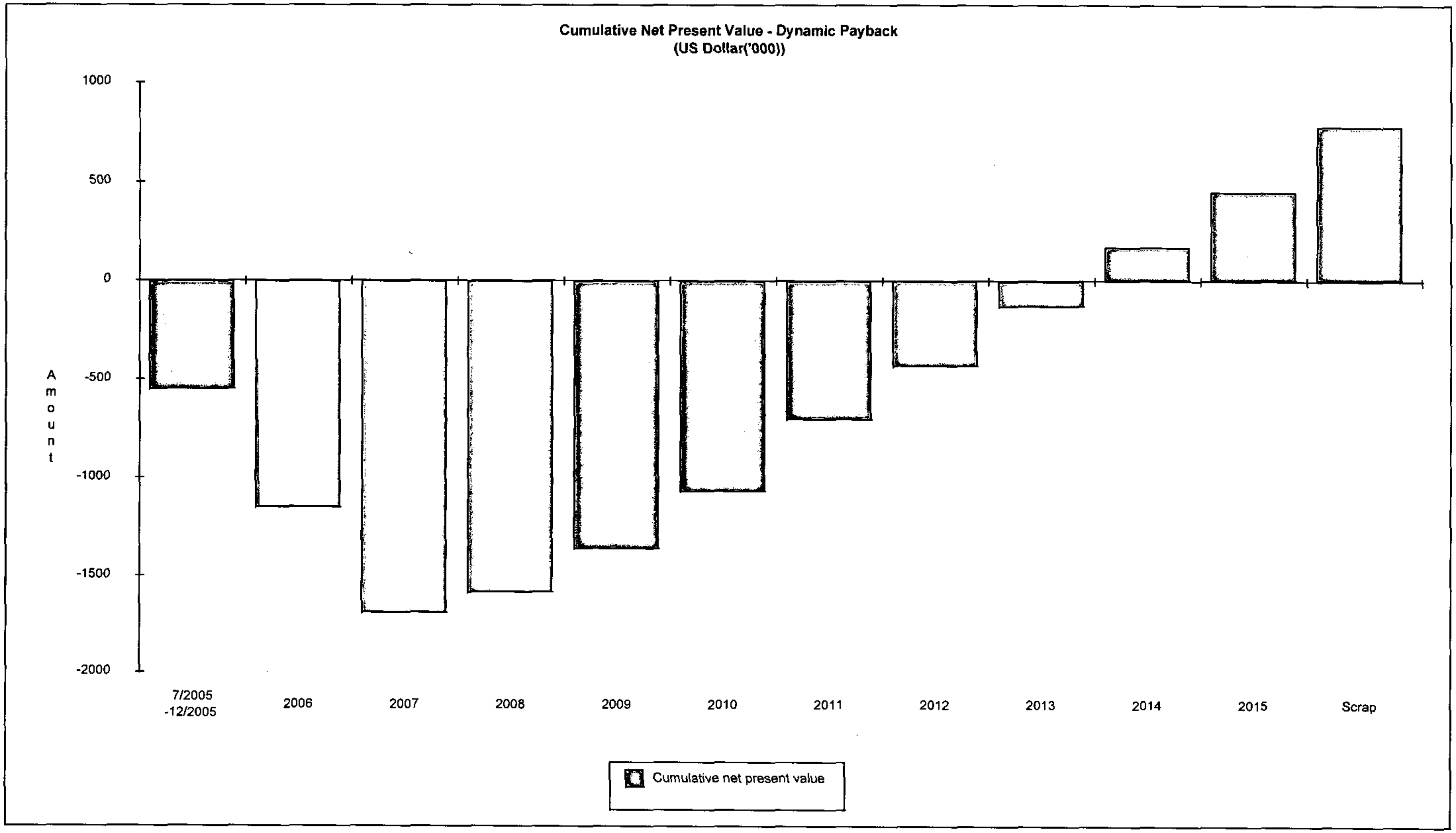
| | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Scrap 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL CASH INFLOW | 0.00 | 0.00 | 0.00 | 1,151.13 | 1,656.73 | 2,325.74 | 3,070.16 | 3,379.82 | 3,709.34 | 3,989.48 | 4,232.39 | 1,093.29 |
| Inflow operation | 0.00 | 0.00 | 0.00 | 1,151.13 | 1,656.73 | 2,325.74 | 3,070.16 | 3,379.82 | 3,709.34 | 3,989.48 | 4,232.39 | 0.00 |
| *Sales revenue* | *0.00* | *0.00* | *0.00* | *1,151.13* | *1,656.73* | *2,325.74* | *3,070.16* | *3,379.82* | *3,709.34* | *3,989.48* | *4,232.39* | *0.00* |
| *Interest on short-term deposits* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Other income | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1,093.29 |
| TOTAL CASH OUTFLOW | 582.16 | 708.57 | 716.94 | 995.10 | 1,290.31 | 1,777.19 | 2,302.70 | 2,743.07 | 2,918.51 | 3,117.75 | 3,318.79 | 0.00 |
| Increase in fixed assets | 582.16 | 708.57 | 716.94 | 40.67 | 62.01 | 99.34 | 127.48 | 387.58 | 72.54 | 75.44 | 16.10 | 0.00 |
| *Fixed investments* | *582.16* | *682.22* | *689.32* | *40.67* | *62.01* | *99.34* | *127.48* | *387.58* | *72.54* | *75.44* | *16.10* | *0.00* |
| *Pre-production expenditures (net of interest)* | *0.00* | *26.35* | *27.61* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Increase in net working capital | 0.00 | 0.00 | 0.00 | 100.01 | 40.75 | 53.70 | 60.50 | 26.14 | 28.37 | 19.90 | 31.11 | 0.00 |
| Operating costs | 0.00 | 0.00 | 0.00 | 818.83 | 1,134.91 | 1,550.18 | 2,016.91 | 2,221.04 | 2,442.43 | 2,603.02 | 2,842.59 | 0.00 |
| Marketing costs | 0.00 | 0.00 | 0.00 | 35.60 | 52.65 | 73.97 | 97.81 | 108.31 | 118.86 | 127.95 | 135.78 | 0.00 |
| Income (corporate) tax | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 256.30 | 291.44 | 293.21 | 0.00 |
| NET CASH FLOW | -582.16 | -708.57 | -716.94 | 156.03 | 366.42 | 548.56 | 767.46 | 636.75 | 790.83 | 871.73 | 913.60 | 1,093.29 |
| CUMULATIVE NET CASH FLOW | -582.16 | -1,290.73 | -2,007.66 | -1,851.63 | -1,485.22 | -936.66 | -169.20 | 467.55 | 1,258.38 | 2,130.10 | 3,043.71 | 4,137.00 |
| Net present value | -550.08 | -597.80 | -540.05 | 104.94 | 220.04 | 294.12 | 367.40 | 272.17 | 301.81 | 297.04 | 277.95 | 332.62 |
| Cumulative net present value | -550.08 | -1,147.89 | -1,687.94 | -1,583.00 | -1,362.96 | -1,068.84 | -701.44 | -429.28 | -127.47 | 169.57 | 447.52 | 780.14 |
| NET PRESENT VALUE | at 12.00% | 780.14 | | | | | | | | | | |
| INTERNAL RATE OF RETURN | 19.13% | | | | | | | | | | | |
| MODIFIED INTERNAL RATE OF RETURN | 19.13% | | | | | | | | | | | |
| NORMAL PAYBACK | at 0.00% | 7.27 years | = 2012 | | | | | | | | | |
| DYNAMIC PAYBACK | at 12.00% | 9.43 years | = 2014 | | | | | | | | | |
| NPV RATIO | 0.34 | | | | | | | | | | | |
| Net present values discounted to | 7/2005 | | | | | | | | | | | |


Sensitivity of IRR (Yearly results)
(US Dollar('000))
IRR
0
5
10
15
20
25
30
35
-20
-15
-10
-5
0
5
10
15
20
Variation (%)
Sales revenue
Increase in fixed assets
Operating costs

| Variation (%) | Sales revenue | Increase in fixed assets | Operating costs |
|---|---|---|---|
| -20.00 % | 1.57 % | 24.32 % | 28.05 % |
| -16.00 % | 5.26 % | 23.16 % | 26.40 % |
| -12.00 % | 9.18 % | 22.07 % | 24.69 % |
| -8.00 % | 12.77 % | 21.04 % | 22.91 % |
| -4.00 % | 16.07 % | 20.06 % | 21.06 % |
| 0.00 % | 19.13 % | 19.13 % | 19.13 % |
| 4.00 % | 21.98 % | 18.25 % | 17.11 % |
| 8.00 % | 24.66 % | 17.41 % | 14.99 % |
| 12.00 % | 27.19 % | 16.61 % | 12.76 % |
| 16.00 % | 29.58 % | 15.84 % | 10.41 % |
| 20.00 % | 31.85 % | 15.10 % | 7.91 % |


Cumulative Net Cash Flow - Normal Payback
(US Dollar('000))
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
Amount
7/2005
-12/2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Scrap
Cumulative net cash flow

| | Cumulative net cash flow |
|---|---|
| 7/2005-12/2005 | -582.16 |
| 2006 | -1,290.73 |
| 2007 | -2,007.66 |
| 2008 | -1,851.63 |
| 2009 | -1,485.22 |
| 2010 | -936.66 |
| 2011 | -169.20 |
| 2012 | 467.55 |
| 2013 | 1,258.38 |
| 2014 | 2,130.10 |
| 2015 | 3,043.71 |
| Scrap | 4,137.00 |


Cumulative Net Present Value - Dynamic Payback
(US Dollar('000))
1000
500
0
-500
-1000
-1500
-2000
Amount
7/2005 -12/2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Scrap
Cumulative net present value

| | Cumulative net *present value* |
|---|---|
| 7/2005-12/2005 | -550.08 |
| 2006 | -1,147.89 |
| 2007 | -1,687.94 |
| 2008 | -1,583.00 |
| 2009 | -1,362.96 |
| 2010 | -1,068.84 |
| 2011 | -701.44 |
| 2012 | -429.28 |
| 2013 | -127.47 |
| 2014 | 169.57 |
| 2015 | 447.52 |
| Scrap | 780.14 |

**DISCOUNTED CASH FLOW - EQUITY CAPITAL INVESTED**
US Dollar('000)

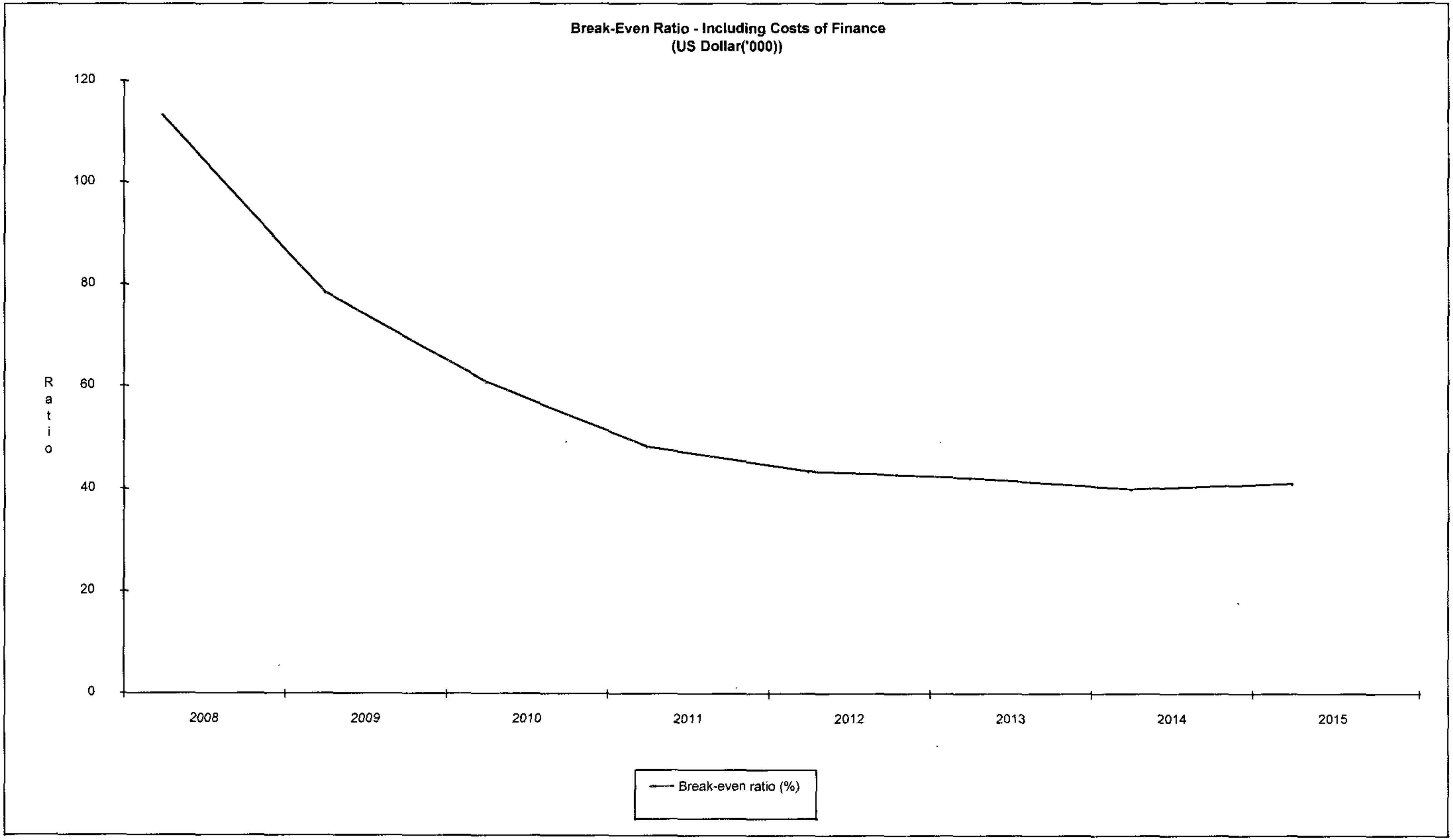
| | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Scrap 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL CASH INFLOW | 0.00 | 15.75 | 30.23 | 109.00 | 317.50 | 243.35 | 460.63 | 328.65 | 481.85 | 562.29 | 913.60 | 1,093.29 |
| Surplus (deficit) | 0.00 | 15.75 | 30.23 | 109.00 | 281.56 | 152.37 | 301.66 | 138.00 | 332.34 | 392.28 | 742.56 | 1,093.29 |
| Dividends | 0.00 | 0.00 | 0.00 | 0.00 | 35.95 | 90.98 | 158.98 | 190.65 | 149.51 | 170.01 | 171.04 | 0.00 |
| Equity capital refund | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TOTAL CASH OUTFLOW | 323.08 | 215.93 | 74.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Equity capital paid | 323.08 | 215.93 | 74.73 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| NET CASH RETURN | -323.08 | -200.18 | -44.49 | 109.00 | 317.50 | 243.35 | 460.63 | 328.65 | 481.85 | 562.29 | 913.60 | 1,093.29 |
| CUMULATIVE NET CASH RETURN | -323.08 | -523.26 | -567.75 | -458.75 | -141.25 | 102.11 | 562.74 | 891.39 | 1,373.23 | 1,935.52 | 2,849.12 | 3,942.42 |
| Net present value | -294.93 | -152.28 | -28.21 | 57.58 | 139.78 | 89.28 | 140.82 | 83.73 | 102.30 | 99.48 | 134.70 | 161.19 |
| Cumulative net present value | -294.93 | -447.21 | -475.42 | -417.83 | -278.06 | -188.78 | -47.96 | 35.77 | 138.07 | 237.55 | 372.25 | 533.43 |
| NET PRESENT VALUE | at 20.00% | 533.43 | | | | | | | | | | |
| INTERNAL RATE OF RETURN | 34.82% | | | | | | | | | | | |
| MODIFIED INTERNAL RATE OF RETURN | 34.82% | | | | | | | | | | | |
| SHORT NET PRESENT VALUE | at 20.00% | 372.25 | for 11 years | | | | | | | | | |
| NORMAL PAYBACK | at 0.00% | 5.58 years | = 2010 | | | | | | | | | |
| DYNAMIC PAYBACK | at 20.00% | 7.57 years | = 2012 | | | | | | | | | |
| NPV RATIO | 1.05 | | | | | | | | | | | |
| Net present values discounted to | 7/2005 | | | | | | | | | | | |

**NET INCOME STATEMENT**
*US Dollar('000)*

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| *Sales revenue* | 1,151.13 | 1,656.73 | 2,325.74 | 3,070.16 | 3,379.82 | 3,709.34 | 3,989.48 | 4,232.39 |
| Less variable costs | 683.36 | 987.58 | 1,390.92 | 1,844.66 | 2,032.13 | 2,233.63 | 2,372.37 | 2,570.72 |
| *Material* | *573.16* | *825.09* | *1,161.96* | *1,540.56* | *1,693.42* | *1,856.65* | *1,960.86* | *2,102.93* |
| *Personnel* | *20.39* | *29.57* | *42.22* | *57.14* | *65.20* | *76.83* | *88.39* | *124.88* |
| *Marketing (except personnel)* | *35.60* | *52.65* | *73.97* | *97.81* | *108.31* | *118.86* | *127.95* | *135.78* |
| *Other variable costs* | *54.20* | *80.27* | *112.77* | *149.15* | *165.20* | *181.30* | *195.17* | *207.12* |
| VARIABLE MARGIN | 467.77 | 669.15 | 934.82 | 1,225.50 | 1,347.69 | 1,475.71 | 1,617.11 | 1,661.68 |
| in % of sales revenue | 40.64 | 40.39 | 40.19 | 39.92 | 39.87 | 39.78 | 40.53 | 39.26 |
| Less fixed costs | 481.90 | 476.45 | 520.04 | 547.27 | 552.08 | 598.47 | 633.75 | 684.30 |
| *Material* | *64.89* | *76.48* | *87.75* | *100.42* | *109.22* | *119.27* | *129.74* | *148.67* |
| *Personnel* | *25.77* | *29.29* | *33.31* | *37.86* | *42.98* | *49.18* | *56.09* | *67.05* |
| *Marketing (except personnel)* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Depreciation* | *310.83* | *276.47* | *286.82* | *277.22* | *254.87* | *270.81* | *275.14* | *276.65* |
| *Other fixed costs* | *80.42* | *94.21* | *112.16* | *131.78* | *145.01* | *159.21* | *172.78* | *191.93* |
| OPERATIONAL MARGIN | -14.13 | 192.70 | 414.78 | 678.22 | 795.61 | 877.23 | 983.36 | 977.37 |
| in % of sales revenue | -1.23 | 11.63 | 17.83 | 22.09 | 23.54 | 23.65 | 24.65 | 23.09 |
| Interest on short-term deposits | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Financial costs | 47.03 | 48.91 | 50.87 | 42.32 | 33.01 | 22.89 | 11.90 | 0.00 |
| GROSS PROFIT FROM OPERATIONS | -61.16 | 143.79 | 363.91 | 635.90 | 762.59 | 854.35 | 971.46 | 977.37 |
| in % of sales revenue | -5.31 | 8.68 | 15.65 | 20.71 | 22.56 | 23.03 | 24.35 | 23.09 |
| Extraordinary income | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Extraordinary loss | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Depreciation allowances | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| GROSS PROFIT | -61.16 | 143.79 | 363.91 | 635.90 | 762.59 | 854.35 | 971.46 | 977.37 |
| Investment allowances | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Deductible loss* | 0.00 | 61.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| TAXABLE PROFIT | 0.00 | 82.63 | 363.91 | 635.90 | 762.59 | 854.35 | 971.46 | 977.37 |
| Income (corporate) tax | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 256.30 | 291.44 | 293.21 |
| NET PROFIT | -61.16 | 143.79 | 363.91 | 635.90 | 762.59 | 598.04 | 680.02 | 684.16 |
| in % of sales revenue | -5.31 | 8.68 | 15.65 | 20.71 | 22.56 | 16.12 | 17.05 | 16.16 |
| Dividends | 0.00 | 35.95 | 90.98 | 158.98 | 190.65 | 149.51 | 170.01 | 171.04 |
| RETAINED PROFIT | -61.16 | 107.84 | 272.93 | 476.93 | 571.95 | 448.53 | 510.02 | 513.12 |
| RATIOS | | | | | | | | |
| Net profit to equity (%) | -9.97 | 23.43 | 59.29 | 103.61 | 124.25 | 97.44 | 110.80 | 111.47 |
| Net profit to net worth (%) | -6.88 | 15.13 | 30.99 | 39.48 | 35.46 | 23.20 | 22.11 | 19.06 |
| Net profit+interest to investment (%) | -0.64 | 8.29 | 16.75 | 25.45 | 25.84 | 19.53 | 21.13 | 20.59 |

**BREAK-EVEN ANALYSIS - TOTAL**
US Dollar('000)

| | Production 2008 | Production 2009 | Production 2010 | Production 2011 | Production 2012 | Production 2013 | Production 2014 | Production 2015 |
|---|---|---|---|---|---|---|---|---|
| Sales revenue | 1,151.13 | 1,656.73 | 2,325.74 | 3,070.16 | 3,379.82 | 3,709.34 | 3,989.48 | 4,232.39 |
| Variable costs | 683.36 | 987.58 | 1,390.92 | 1,844.66 | 2,032.13 | 2,233.63 | 2,372.37 | 2,570.72 |
| Variable margin | 467.77 | 669.15 | 934.82 | 1,225.50 | 1,347.69 | 1,475.71 | 1,617.11 | 1,661.68 |
| Variable margin ratio (%) | 40.64 | 40.39 | 40.19 | 39.92 | 39.87 | 39.78 | 40.53 | 39.26 |
| Including cost of finance | | | | | | | | |
| Fixed costs | 481.90 | 476.45 | 520.04 | 547.27 | 552.08 | 598.47 | 633.75 | 684.30 |
| Financial costs | 47.03 | 48.91 | 50.87 | 42.32 | 33.01 | 22.89 | 11.90 | 0.00 |
| Break-even sales value | 1,301.64 | 1,300.73 | 1,420.37 | 1,477.08 | 1,467.34 | 1,561.85 | 1,592.84 | 1,742.97 |
| Break-even ratio (%) | 113.07 | 78.51 | 61.07 | 48.11 | 43.41 | 42.11 | 39.93 | 41.18 |
| Fixed costs coverage ratio | 0.88 | 1.27 | 1.64 | 2.08 | 2.30 | 2.37 | 2.50 | 2.43 |
| Excluding cost of finance | | | | | | | | |
| Fixed costs | 481.90 | 476.45 | 520.04 | 547.27 | 552.08 | 598.47 | 633.75 | 684.30 |
| Break-even sales value | 1,185.91 | 1,179.63 | 1,293.82 | 1,371.05 | 1,384.55 | 1,504.32 | 1,563.48 | 1,742.97 |
| Break-even ratio (%) | 103.02 | 71.20 | 55.63 | 44.66 | 40.97 | 40.55 | 39.19 | 41.18 |
| Fixed costs coverage ratio | 0.97 | 1.40 | 1.80 | 2.24 | 2.44 | 2.47 | 2.55 | 2.43 |


Break-Even Ratio - Including Costs of Finance
(US Dollar('000))
120
100
80
60
40
20
0
Ratio
2008
2009
2010
2011
2012
2013
2014
2015
Break-even ratio (%)

| | Break-even ratio (%) |
|---|---|
| 2008 | 113.07 |
| 2009 | 78.51 |
| 2010 | 61.07 |
| 2011 | 48.11 |
| 2012 | 43.41 |
| 2013 | 42.11 |
| 2014 | 39.93 |
| 2015 | 41.18 |

**PROJECTED BALANCE SHEET**
US Dollar('000)

| | 7/2005 -12/2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL ASSETS | 582.16 | 1,335.81 | 2,145.45 | 2,218.95 | 2,383.20 | 2,401.61 | 2,668.12 | 3,002.83 | 3,193.77 | 3,423.34 | 3,942.36 |
| Total current assets | 0.00 | 15.75 | 45.99 | 283.27 | 614.95 | 833.10 | 1,208.65 | 1,378.90 | 1,746.11 | 2,163.93 | 2,943.50 |
| *Inventory on materials & supplies* | *0.00* | *0.00* | *0.00* | *5.03* | *7.24* | *10.17* | *13.44* | *14.79* | *16.23* | *17.36* | *18.47* |
| *Work in progress* | *0.00* | *0.00* | *0.00* | *1.94* | *2.71* | *3.73* | *4.88* | *5.37* | *5.89* | *6.26* | *6.81* |
| *Finished product* | *0.00* | *0.00* | *0.00* | *31.84* | *44.14* | *60.28* | *78.44* | *86.37* | *94.98* | *101.23* | *110.55* |
| *Accounts receivable* | *0.00* | *0.00* | *0.00* | *89.00* | *123.70* | *169.18* | *220.28* | *242.64* | *266.80* | *284.48* | *310.25* |
| *Cash-in-hand* | *0.00* | *0.00* | *0.00* | *0.47* | *0.62* | *0.81* | *1.03* | *1.15* | *1.29* | *1.42* | *1.67* |
| *Short-term deposits* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Cash surplus, finance available* | *0.00* | *15.75* | *45.99* | *154.99* | *436.55* | *588.92* | *890.58* | *1,028.58* | *1,360.91* | *1,753.19* | *2,495.76* |
| Total fixed assets, net of depreciation | 582.16 | 1,320.06 | 2,080.48 | 1,810.31 | 1,595.85 | 1,408.37 | 1,258.63 | 1,391.34 | 1,193.07 | 993.37 | 732.81 |
| *Fixed investments* | *0.00* | *582.16* | *1,264.38* | *1,953.70* | *1,994.36* | *2,056.37* | *2,155.71* | *2,283.19* | *2,670.77* | *2,743.31* | *2,818.75* |
| *Construction in progress* | *582.16* | *682.22* | *689.32* | *40.67* | *62.01* | *99.34* | *127.48* | *387.58* | *72.54* | *75.44* | *16.10* |
| *Total pre-production expenditures* | *0.00* | *55.68* | *126.78* | *126.78* | *126.78* | *126.78* | *126.78* | *126.78* | *126.78* | *126.78* | *126.78* |
| *Less accumulated depreciation* | *0.00* | *0.00* | *0.00* | *310.83* | *587.30* | *874.12* | *1,151.34* | *1,406.21* | *1,677.02* | *1,952.16* | *2,228.81* |
| *Less depreciation allowance* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Accumulated losses brought forward | 0.00 | 0.00 | 0.00 | 0.00 | 61.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Loss in current year | 0.00 | 0.00 | 0.00 | 61.16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Exchange rate losses | 0.00 | 0.00 | 18.99 | 64.21 | 111.24 | 160.15 | 200.84 | 232.59 | 254.59 | 266.04 | 266.04 |
| TOTAL LIABILITIES | 582.15 | 1,335.81 | 2,145.45 | 2,218.95 | 2,383.20 | 2,401.61 | 2,668.12 | 3,002.83 | 3,193.77 | 3,423.34 | 3,942.36 |
| Total current liabilities | 0.00 | 0.00 | 0.00 | 28.28 | 37.65 | 49.72 | 63.12 | 69.23 | 75.73 | 81.37 | 87.27 |
| *Accounts payable* | *0.00* | *0.00* | *0.00* | *28.28* | *37.65* | *49.72* | *63.12* | *69.23* | *75.73* | *81.37* | *87.27* |
| *Total short-term debt* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Total long-term debt | 0.00 | 395.61 | 1,130.52 | 1,175.74 | 1,222.77 | 1,017.35 | 793.53 | 550.18 | 286.09 | 0.00 | 0.00 |
| Total equity capital | 582.15 | 940.20 | 1,014.93 | 1,014.93 | 1,014.93 | 1,014.93 | 1,014.93 | 1,014.93 | 1,014.93 | 1,014.93 | 1,014.93 |
| *Ordinary capital* | *323.08* | *539.01* | *613.74* | *613.74* | *613.74* | *613.74* | *613.74* | *613.74* | *613.74* | *613.74* | *613.74* |
| *Preference capital* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| *Subsidies, grants* | *259.07* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* | *401.19* |
| Reserves, retained profit brought forward | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 46.68 | 319.61 | 796.54 | 1,368.48 | 1,817.02 | 2,327.03 |
| Retained profit | 0.00 | 0.00 | 0.00 | 0.00 | 107.84 | 272.93 | 476.93 | 571.95 | 448.53 | 510.02 | 513.12 |
| Net worth | 582.15 | 940.20 | 995.94 | 889.56 | 950.37 | 1,174.39 | 1,610.63 | 2,150.83 | 2,577.36 | 3,075.93 | 3,589.05 |
| RATIOS | | | | | | | | | | | |
| Equity to total liabilities (%) | 100.00 | 70.38 | 47.31 | 45.74 | 42.59 | 42.26 | 38.04 | 33.80 | 31.78 | 29.65 | 25.74 |
| Net worth to total liabilities (%) | 100.00 | 70.38 | 46.42 | 40.09 | 39.88 | 48.90 | 60.37 | 71.63 | 80.70 | 89.85 | 91.04 |
| Long-term debt to net worth | 0.00 | 0.42 | 1.14 | 1.32 | 1.29 | 0.87 | 0.49 | 0.26 | 0.11 | 0.00 | 0.00 |
| Current assets to current liabilities | 0.00 | 0.00 | 0.00 | 10.02 | 16.33 | 16.75 | 19.15 | 19.92 | 23.06 | 26.59 | 33.73 |

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